0020

C/007/005 incoming
cc: Karl

Canyon Fuel Company, LLC.
Skyline Mine
A Subsidiary of Arch Western Bituminous Group, LLC.

COPY

Austin Belcher, Environ. Engineer
HCR 35, Box 380
Helper, UT 84526
(435) 448-2668 - Office
(435) 448-2632 - Fax

#3519

March 29, 2010

Mr. Daron R. Haddock
Permit Supervisor
Utah Division of Oil, Gas and Mining
1594 West North Temple, Suite 1210
Salt Lake City, Utah 84114-5801

RE: 2009 Annual Report, Canyon Fuel Company, LLC. Skyline Mine, C/007/005,

Dear Mr. Haddock:

Please find enclosed with this letter two (2) copies of the 2009 Annual Report and a CD containing the 2009 As Mined and Subsidence Maps.

If you have any questions, please call me at (435) 448-2668.

Sincerely:

Austin Belcher
Environmental Engineer, Skyline Mine
Canyon Fuel Company, LLC.

Enclosures

File in:
❑ Confidential
☒ Shelf
❑ Expandable
Refer to Record No 0020 Date 03292010
In C 0070005 2010 Incoming
For additional information Confidential

RECEIVED
MAR 30 2010
DIV. OF OIL, GAS & MINING

This Annual Report shows information the Division has for your mine. Please review the information to see if it is current. If the information needs to be updated please do so in this document. At the end of each section the operator is asked to verify if the information is correct. Please answer these questions and make all comments on this document. Submit the completed document and any additional information identified in the Appendices to the Division by April 30, 2010. During a complete inspection an inspector will check and verify the information. To enter text, click in the cell and type your response. You can use the tab key to move from one field to the next. To enter an X in a box, click next to the box, right click, and select properties, then the checked circle, then hit enter, or hit the unchecked circle if the X is to be removed.

GENERAL INFORMATION

Permittee Name	Canyon Fuel Company, LLC
Mine Name	Skyline Mine
Operator Name (If other then permittee)	
Permit Expiration Date	April 30, 2012
Permit Number	C/007/0005
Authorized Representative Title	Wess Sorensen, Mine Manager
Phone Number	(435) 448-2619
Fax Number	(435) 448-2632
E-mail Address	wsorensen@archcoal.com
Mailing Address	Skyline Mine HRC 35 Box 380 Helper, UT 84526
Designated Representative	Gregg Galecki
Resident Agent	Corporation Trust Company
Resident Agent Mailing Address	Corporation Trust Company 1209 Orange Street Wilmington, DE
Number of Binders Submitted	2

RECEIVED
MAR 30 2010
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Operator, please update any incorrect information.

IDENTIFICATION OF OTHER PERMITS

Identify other permits that are required in conjunction with mining and reclamation activities.

Permit Type	ID Number	Description	Expiration Date
MSHA Mine ID(s)	1211-UT-09-01566	Skyline Mine #3	N/A
	1211-UT-0901566-01	Skyline Mine Waste Rock Disposal	N/A
MSHA Impoundment(s)	None		
NPDES/UPDES Permit(s)	UT 0023540-01, 02, 03, 004(inactive)	UPDES Permit for Skyline Mine, Rail Loadout, Waste Rock Disposal Site, Winter Quarters Ventilation pand	11/30/14
Storm Water Permit	UT0023540	Incorporated into UPDES Permit	11/30/14
PSD Permit(s) (Air)	10092	Official Site Identification	N/A
	147-98	Approval Order	
Other			
MSHA Mine ID(s)	1211-UT-09-01566-03	Skyline Temporary Waste Rock Disposal Site	N/A

Operator, please update any incorrect information.

CERTIFIED REPORTS

List the certified inspection reports as required by the rules and under the approved plan that must be periodically submitted to the Division. Specify whether the information is included as Appendix A to this report or currently on file with the Division.

Certified Reports:	**Required** Yes	No	**Included** Included	**or**	**DOGM file location** Vol, Chapter, Page
Excess Spoil Piles	☐	☒	☐		
Refuse Piles	☒	☐	☐		Submitted via email on 4/13/09, 7/23/09, 11/3/09, 1/25/10
Impoundments	☒	☐	☐		Submitted via email on 1/25/10
Other					
	☐	☐	☐		
	☐	☐	☐		

Operator Comments:

Inspector:
Has the operator complied with this section? Yes ☐ No ☐
Inspector Comments:

COMMITMENTS AND CONDITIONS

The Permittee is responsible for ensuring annual technical commitments in the MRP and conditions accepted with the permit are completed throughout the year. The Division has identified these commitments below and has provided space for you to report what you have done during the past year for each commitment. If the particular section is blank, no commitment has been identified and no response is required for this report. If additional written response is required, it should be filed under Appendix B to this report.

Admin R645-301-100
Soils R645-301-200

Title: WASTE ROCK SAMPLING
Objective: To document chemical characteristics and support reclamation plan using less than four feet of cover and to protect surface and groundwater.
Frequency: During periods of deposition at the waste rock site.
Status: Quarterly sampling, 1 sample per 2000 tons hauled to disposal site.
Reports: Annual reporting.
Citation: Vol. 3, Section 4.4, pg. 4-30, 2nd para. And 1988 Soils Guidelines Table 6.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☐ Not required this year. ☒ If yes, comment;
Operator Comments:
Skyline deposited only approximately 900-1,000 tons of material to the site in 2009. Material consisted of native colluvium that had accumulated under the Overland conveyor.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: SUBSOIL SAMPLING AT WASTE ROCK SITE.
Objective: To provide chemical characteristics of purchased subsoil.
Frequency: Sample purchased subsoil for parameters in Table 1 of the Utah 1988 Guidelines.
Status: Ongoing with contemporaneous reclamation at the waste rock site.
Reports: None specified. Suggest verbal communication with Division and lab analysis to be included in bond release application.
Citation: Vol. 3, Section 4.6.4.1, pg. 4-38a, 3rd para. And pg. 4-38b.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
Skyline Mine did not purchase any subsoil in 2009 for contemporaneous reclamation activities.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: SAMPLING PRIOR TO SLURRY PLACEMENT IN ABANDON UNDERGROUND WORKINGS.
Objective: Protection of groundwater.
Frequency: Every 450 ft. of advance.
Status: Ongoing.
Reports: Notification if parameters are out of compliance with Guidelines for Topsoil and Overburden.
Citation: Volume 2, Incorporation of 97K-1and Section 1.2 (at the end of Section 3.2) and Section 3.2.8.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
Skyline did not pump any slurry into abandoned underground workings in 2009.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: SAMPLING OF WASTE ROCK IN TEMPORARY STOCKPILES.
Objective: Protection of surface and groundwater.
Frequency: If remains in temporary location longer than three months.
Status: 1 sample/ 2000 tons of temporary stockpiled material.
Reports: Annual reporting not specified, but assumed to be the same as disposal site sampling (previous paragraph on same page).
Citation: Vol. 3, Section 4.4, pg. 4-30, 3rd para. And 1988 Soils Guidelines Table 6.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
The temporary stockpile remained small throughout 2009, requiring no sampling.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: CULTURAL RESOURCES
Objective: If during the course of mining operations, previously unidentified cultural resources are discovered, the Permittee shall ensure that the site(s) is not disturbed and shall notify the Division of Oil, Gas, and Mining. The Division, after coordination with OSM, shall inform the Permittee of necessary actions required. The Permittee shall implement the mitigation measures required by the Division within the time frame specified by the Division.
Frequency: As needed.
Status: Ongoing.
Reports: Annual.
Citation: Permit Condition Sec. 16.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
No previously unidentified cultural resources were discovered in 2009.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: MACROINVERTEBRATE SURVEYS
Objective: To determine if mining and mining related activities are impacting the perennial streams located in Woods, Eccles, Burnout and James Canyons.
Frequency: Fall and Spring every three years beginning in 2007.
Status: Reports are **Overdue**. Sampling has been conducted in 2007 and 2008.
Reports: Annual.
Citation: Appendix A-3, Volume 2, The Macro benthos of Burnout and James Canyon Creek. Benthos of Boardinghouse & Eccles Creek, Fall 2001. Macroinvertebrates of Eccles Creek, October 2004. Volume 1A, Section 2.8, pages 2-71, 71A, B, C, Section 2.8, table 2.8-1a.

Operator: Has this commitment been acted on this year?

Yes ☒ No ☐ Not required this year. ☒ If yes, comment;
Operator Comments:
The 2007-2008 reports for James, Burnout, Eccles, Woods Canyons are submitted.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: FISH SURVEYS
Objective: To determine if mining and mining related activities are impacting the perennial streams located in Eccles Canyon.
Frequency: In the Fall Every three years beginning in 2007.
Status: Ongoing. Most recent surveys were conducted in 2007. Next survey due in 2010.
Reports: Annual.
Citation: Volume 1A, Section 2.8, page 2-71.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
The next scheduled electro fishing exercise is in 2010.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: Vegetation survey program for the Winter Quarters and Woods Stream channels.
Objective: Baseline and monitoring surveys for vegetation along stream channels.
Frequency: Baseline survey of entire length of channels in 2005, monitoring surveys two years prior and during undermining of specific lengths of the channels, and follow-up surveys two years after undermining.
Status: Ongoing
Reports: Division's Annual Report
Citation: Vol. A-2 2nd volume; Vol. A-3 2nd volume.

Operator: Has this commitment been acted on this year?

Yes ☒ No ☐ Not required this year. ☐ If yes, comment;
Operator Comments:
The Mt. Nebo report is included with this report.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: TOPSOIL SAMPLING.
Objective: To determine fertilizer application rate.
Frequency: At final reclamation sample topsoil for N, P, K, Fe, Mg, Mn, Zn, Ca and pH.
Status: Analysis of redistributed topsoil.
Reports: None specified. Suggest verbal communication with Division and lab analysis to be included in bond release application.
Citation: Vol. 3, Section 4.5, pg. 4-32, 2nd para.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
No soil was redistributed in 2009.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Landuse, Cultural Resources, Air Quality R645-301- 400

Engineering R645-301-500

Geology R645-301-600

Hydrology R645-301-700

Title: Age-monitoring of Water.
Objective: Understand possible sources of groundwater inflows
Frequency: When inflows of 800 gpm are encountered.
Status: No significant inflows in the North Lease.
Reports: As needed.
Citation: Volume 1, Page 2-35b, Paragraph 2.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
No sustained inflows >800 gpm have been encountered in the North Lease area of Mine #3. No additional age-dating water analysis was collected in 2009.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: Measurement of Sediment Yield.
Objective: Understand how much excess sediment the mine is contributing to Eccles Creek.
Frequency: Annually.
Status: Ongoing.
Reports: Annually.
Citation: Volume 1a, Page 2-43a, Paragraph 2.

Operator: Has this commitment been acted on this year?

Yes ☐ No ☒ Not required this year. ☐ If yes, comment;
Operator Comments:
This study was discontinued per Section 2.4.4 (pages 2-45 and 2-46) of M&RP). Average discharges are currently below 5,000 gpm.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: North Lease Perennial Stream Flow Measurement.
Objective: Understand the impact of longwall mining on perennial portions of streams in Winter Quarters and Woods Canyons.
Frequency: Monthly, June through October and when accessible, 1 year prior to, during and 1 year after undermining.
Status: Ongoing.
Reports: Quarterly to database - we should ask fo a better map, or list of undermined dates for these sites yearly, otherwise it is impossible to tell if they are within the timeframes.
Citation: Volume 1a, Page 2-44a, Paragraph 5.

Operator: Has this commitment been acted on this year?

Yes ☒ No ☐ Not required this year. ☐ If yes, comment;
Operator Comments:
Monthly monitoring was conducted June through October 2009 with the information provided in the Database. An amendment to the monitoring program was approved in 2009 which reduced the number of sampling locations based on multiple year monitoring. Additional monitoring sites will be both added and dropped from the program as mining advances.
Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Title: Monthly Reporting of Pumped Flows to Electric Lake and Eccles Creek.
Objective: Be aware at all times, of the volume of water being pumped out of the Skyline Mine, and to which drainage.
Frequency: Cumulative monthly flows.
Status: Ongoing.
Reports: Monthly - first week.
Citation: Permit Condition 2.

Operator: Has this commitment been acted on this year?

Yes ☒ No ☐ Not required this year. ☐ If yes, comment;
Operator Comments:
The information continues to be updated and provided to the Division on a monthly basis.

Inspector:
Has the operator complied with this commitment? Yes ☐ No ☐
Inspector Comments:

Bonding & Insurance R645-301-800

Other Commitments

*Reminder: If equipment has been abandoned during 2009, an amendment must be submitted that includes a map showing its location, a description of what was abandoned, whether there were any hazardous or toxic materials and any revision to the PHC as necessary.

REPORTING OF OTHER TECHNICAL DATA

List other technical data and information as required under the approved plan, which must be periodically submitted to the Division. Specify whether the information is included as Appendix B to this report or currently on file with the Division.

Operator Comments:

Inspector:
Has the operator complied with this section? Yes ☐ No ☐
Inspector Comments:

LEGAL, FINANCIAL, COMPLIANCE AND RELATED INFORMATION

Change in administration or corporate structure can often bring about necessary changes to information found in the mining and reclamation plan. The Division is Requesting that each permittee review and update the legal, financial, compliance and related information in the plan as part of the annual report. Please provide the Department of Commerce, Annual Report of Officers, or other equivalent information as necessary to ensure that the information provided in the plan is current. Provide any other change as necessary regarding land ownership, lease acquisitions, legal results from appeals of violations, or other changes as necessary to update information required in the mining and reclamation plan. Include certified financial statements, audits or worksheets, which may be required to meet bonding requirements. Specify whether the information is currently on file with the Division or included as Appendix C to the report.

Legal / Financial Update	Required Yes	No	Included Included or DOGM File location Vol, Chapter, Page
Department of Commerce, Annual Report Officers	☐	☐	☐
Other			
Officers and Directors	☒	☐	☐ Submitted by V. Miller in March 2010. Stand-alone Volume "General Chapter 1"
	☐	☐	☐
	☐	☐	☐

Operator Comments:

Inspector:
Has the operator complied with this section? Yes ☐ No ☐
Inspector Comments:

MAPS

Copies of mine maps, current and up-to-date through at least December 31, 2009, are to be provided to the Division as Appendix D to this report in accordance with the requirements of R 645-301-525.240. The map copies shall be made in accordance with 30 CFR 75.1200 as required by MSHA. Mine maps are not considered confidential. (Please provide a CD.)

Confidential information is limited to:

R645-300-124.310. Information that pertains only to the analysis of the chemical and physical properties of the coal to be mined, except information on components of such coal which are potentially toxic in the environment.

R645-300-124.330. Information on the nature and location of archeological resources on public land and Indian land as required under the Archeological Resources Protection Act of 1979 (P. L. 96-95, 93 Stat. 721, 16 U.S.C. 470).

R645-301-322, Fish and Wildlife Information; R645-301-322.100, the scope and level of detail for such information will be determined by the Division in consultation with state and federal agencies with responsibilities for fish and wildlife and will be sufficient to design the protection and enhancement plan required under R645-301-333 and R645-301-322.230, other species or habitats identified through agency consultation as requiring special protection under state or federal law; R645-301-333.300, Include protective measures that will be used during the active mining phase of operation.

The Division will provide procedures, including notice and opportunity to be heard for persons both seeking and opposing disclosure.

Map Number(s) **Map Title/ Description**

Annual subsidence map	Cumulative Subsidence 1982 - 2009		
Mine map	Skyline Mine; Mine 3 – Levels 2 and 3; As Mined 2009		
Other maps		**Confidential** Yes	No
Projected Mining	Skyline Mine 3 – Level 3; Projected Mining January 2010 through 2020	☒	☐
		☐	☐
		☐	☐
		☐	☐
		☐	☐
		☐	☐
		☐	☐
		☐	☐

Operator Comments:

Inspector:
Has the operator complied with this section? Yes ☐ No ☐
Inspector Comments:

OTHER INFORMATION

Please provide any comments of further information to be included as part of the Annual Report. Any other attachments are to be provided as Appendix E to this report. If information is submitted as a group rather then by individual mine, please identify each of the mine's data in the list below.

Additional attachment to this report? **Yes** ☐ **No** ☐

Operator Comments:

Inspector:
Has the operator complied with this section? Yes ☐ No ☐
Inspector Comments:

APPENDIX A

Certified Reports

Excess Spoil Piles
Refuse Piles
Impoundments

As required under R645-301-514

CONTENTS
None to submit

APPENDIX B

Reporting of Technical Data

Including monitoring data, reports, maps, and other information
As required under the approved plan or as required by the Division

In accordance with the requirement of R645-310-130 and R645-301-140

CONTENTS

Riparian Plant Community Monitoring Report for Selected Reaches in Winter Quarters Canyon
2009

Prepared by

MT. NEBO SCIENTIFIC, INC.
330 East 400 South, Suite 6
Springville, Utah 84663
(801) 489-6937

by

Patrick D. Collins, Ph.D.

for

CANYON FUEL COMPANY, LLC.
Skyline Mines
HC 35 Box 380
Helper, Utah 84526

March 2010

Table of Contents

Introduction

Study Objectives

Underground coal mining activities are currently being conducted below Winter Quarters Canyon in Carbon County, Utah. As a means to monitor the potential impacts to the riparian plant communities that are supported along the streamsides located above the mining, baseline and yearly monitoring data have been collected within these zones. The studies have been conducted before, during and after the mining activities. The first such study began in 2005 with the objective to provide a comprehensive baseline dataset of representative stream reaches for the *entire area* in Winter Quarters (and Woods Canyons), or those that could potentially be impacted by future underground mining. The 2005 monitoring year has been called the *Initial Baseline Year* for the riparian studies.

Regular monitoring of the riparian zones should provide data to determine long-term trends, natural variability and benchmark information including the possible impacts to the riparian plant communities caused by mining beneath the creeks and streams of the canyons. The studies have been designed so that the sample frequency is intensified in the areas where: 1) underground mining is planned for the near future (for more baseline data), 2) where mining is currently occurring, and 3) where mining has occurred in the recent past.

The methodologies used in the studies have been consistent for all monitoring periods. They were not designed to provide data that could show *subtle* changes to community structure and species composition as a result of *minor* changes to the riparian habitat (which can occur as a result of several factors i.e. precipitation changes). Rather, the studies were designed to be compared with future monitoring studies in an attempt to document *major* impacts to the plant communities along the stream due to catastrophic events, such as loss of water and habitat from the effects of subsidence caused from underground mining.

The Study Areas

Winter Quarters Canyon is located within the Wasatch Plateau, a high plateau that lies between the Colorado Plateau and Great Basin regions of the western United States. The canyon is located approximately 3 miles west of the town of Scofield, Utah. The study areas of Winter Quarters Canyon are located within the Manti-La Sal National Forest.

Geologically, most of the area is Cretaceous in age with formations present that include the Price River, North Horn, and Blackhawk formations. The dominant plant communities of these canyons were riparian, spruce-fir, aspen/grass, sagebrush/grass and mountain herblands.

Methods

Sample Design, Transect Placement & Frequency

The riparian vegetation of specific reaches in Winter Quarters Canyon were surveyed in late-August and early-September, 2009. Selection of the sample locations of the reaches were based on the underground coal mining schedule of the Skyline Mines. Like 2006 - 2008, the methods for 2009 follow the *Initial Baseline Year* (2005) described above. The riparian vegetation surveys have been designed to concentrate on recently mined areas, current mining, and areas to be mined in the near future. More specifically, the surveys have been conducted where mining activities are planned under the streams according to the following schedule: 1) two years prior to mining specific areas, 2) the year of the mining activities, and 3) two years after mining has occurred in the areas. During these study periods, sampling will be intensified by placing sample stations at regular intervals every 400 ft., rather than the 800 ft. spacing that was used in the *Baseline Year*. [***NOTE***: *In the Initial Baseline Year (2005) sample locations were placed every 800 ft with the exception of those areas that were scheduled to be mined in late-2005; in those areas the 400 ft spacing was used*].

Line transects were placed at each sample station. Locations and extent of the transects were semi-permanently marked using numbered and flagged wooden stakes and 12-inch metal rods. The vegetation monitoring methods of the studies have been primarily based on those described by the USDA Forest Service manual for a *"Level III Riparian Area Evaluation"* (Integrated Riparian Evaluation Guide, March 1992). Qualitative and quantitative data were recorded at the sample stations established in the field. In the first year of the studies, the overall objective of the study plan was to begin monitoring years with one complete baseline dataset for all riparian areas near the perennial streams located in the mine permit area prior to any mining. As mentioned, in the subsequent monitoring years, sample station locations have been determined and mapped based on the time period schedule for the proposed underground mining activities.

TABLE 1: RIPARIAN COMPLEX DATA SHEET

CLIENT:
COMPLEX: Riverine - Number
WATERBODY NAME:
LOCATION:
DATE:
OBSERVER(S):
QUAD NAME:
GEOLOGIC PARENT MATERIAL:
ASPECT:
STREAM GRADIENT:
ELEVATION: .
ADJACENT UPLAND VEGETATION (looking downstream)
Left: Right:
VEGETATIVE DESCRIPTION (Dominance by Community Types)
SUCCESSIONAL STATUS:
APPARENT FORAGE TREND:
ESTIMATED FORAGE PRODUCTION:
BEAVER ACTIVITY:
PHOTOGRAPH TAKEN:
LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA:
SPECIES OBSERVED:
POOL ATTRIBUTES
- % area in pools:
- % pool area made up of pools > 2' deep:

AQUATIC VEGETATION
- % streambed with filamentous algae:
- % stream margin with rooted aquatic:

BANK TYPE & VEGETATION OVERHANG
- % bank length undercut (<90°):
- % bank length gently sloping (>135°):
- % bank length with overhanging vegetation:

BANK CONDITION (bankfull area only)
- % bank length vegetated, stable:
- % bank length unvegetated, stable:
- % bank length vegetated, unstable:
- % bank length unvegetated, unstable:

NOTES:
QUANTITATIVE DATA SUMMARY:
PHOTOGRAPHIC DOCUMENTATION:

Geomorphological stream channel data outlined in the Level III protocol were not recorded as part of this study because Canyon Fuel Company has conducted other studies that will suffice for this information. Additionally, soils information through the Natural Resources Conservation Service (NRCS) were not available for the study areas.

Qualitative Data

The "Riparian Complex Data Sheet" shown on Table 1 lists all of the qualitative and quantitative data that has been, and will continue to be, collected in the future at each sample station.

Photographic stations for documentation and future comparisons have also been established at each sample location. A sample location map has been included in this report.

Quantitative Data

USDA Forest Service protocol was employed as a model to drive the study plan for quantitative data. *Community Type Cover* is one method to record cover in the USFS Level III protocol. At the sample locations, transect lines have been placed across (or perpendicular to) the stream channel. By design, the line transects vary in lengths which are based on several factors. Although sometimes limited by topographical features, the intent was to make the transects long enough to cover the entire stream, its riparian communities, plus an additional 10 ft on each side of the stream to record the adjacent upland communities. Monitoring the total extent of the riparian plant communities including some upland community data should provide information about possible increases or decreases in the riparian communities relative to the adjacent upland communities.

Once the transects were placed, the line-intercept method was employed to measure the extent of each major riparian plant community. The plant communities have been named by the dominant two plant species. If only one species dominates the community by a wide margin, the plant community was named by this single species. In this report, when reference is made to the left or right side of the drainage, this means "river left" or "river right", *as characterized by looking downstream.*

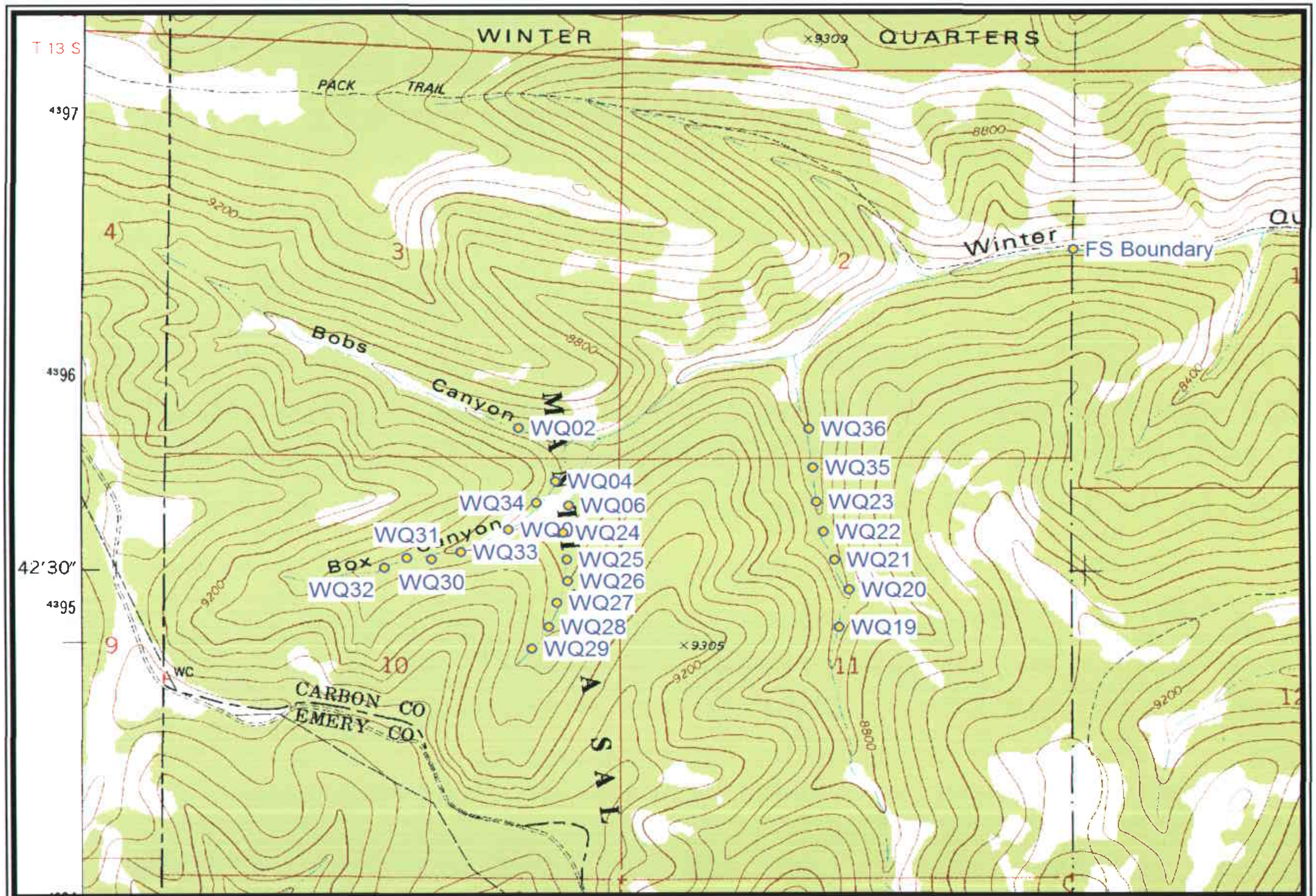
Results & Discussion

Listed below is a summary of the sample stations for the study areas in 2009 (Table 2). For a map of the locations, refer to the *Sample Station Locations for 2009 in Winter Quarters Canyon* in this report.

TABLE 2: Riparian Sample Stations in Winter Quarters Canyon: 2009

Section 11 Drainage	No-Name Drainage	Box Canyon	Bob's Canyon
WQ-19	WQ-06	WQ-04	WQ-02
WQ-20	WQ-24	WQ-34	
WQ-21	WQ-25	WQ-03	
WQ-22	WQ-26	WQ-33	
WQ-23	WQ-27	WQ-30	
WQ-35	WQ-28	WQ-31	
WQ-36	WQ-29	WQ-32	

Sample results are shown for each site on the data sheets provided in this report. Each sheet shows all qualitative and quantitative data recorded as well as photographic documentation.



Sample Locations for 2009 in Winter Quarters Canyon (Base Map: USGS Scofield, UT 7.5 minute series)

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-19

WATERBODY NAME: Winter Quarters Canyon Creek (Section 11 tributary)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-2 ^{o}

ELEVATION: 8,633ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Aspen Right: Spruce/Fir

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 400 lbs/acre

BEAVER ACTIVITY: Historical activity lower in this drainage.

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
Populus tremuloides		*Delphinium barbeyi*	*Poa secunda*
		Epilobium sp.	
		Geranium richardsonii	
		Osmorhiza obtusa	
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	
		Viguiera multiflora	

POOL ATTRIBUTES
% area in pools: 50
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 50 (Racy)

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 20
% bank length gently sloping (>135°): ±10
% bank length with overhanging vegetation: 20

BANK CONDITION
% bank length vegetated, stable: 70
% bank length unvegetated, stable: 25
% bank length vegetated, unstable: 0
% bank length unvegetated, unstable: 5

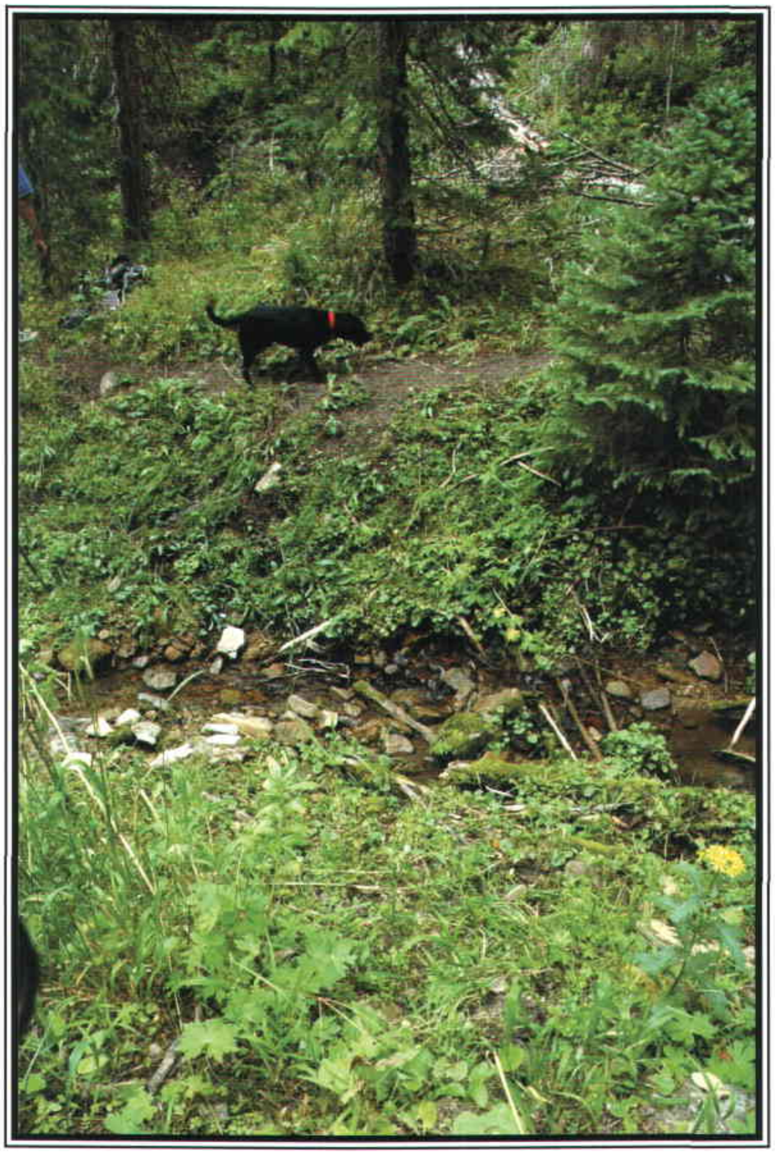
NOTES:

1) Site located just upstream from a spring area.
2) Placed site upstream from the spring to decrease influence of the stream water.
3) Left hillside was sloughing in this area.
4) Transect length was 31' in 2006, then to 30' in 2007, 27' in 2008, 27' in 2009.

DATA SUMMARY

WQ-19: Cover by community types in Winter Quarters Canyon (2009).	
UPLAND VEGETATION	Cover (ft)
	7.00
	7.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Ranunculus cymbalaria	9.00
TOTAL COVER (Upland Species)	14.00
TOTAL COVER (Riparian Species)	9.00
ROCK (channel)	1.00
WATER (channel)	3.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	27.00

PHOTOGRAPHIC DOCUMENTATION



WQ-19

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: *Canyon Fuel Company, Skyline Mines*

COMPLEX: Number WQ-20

WATERBODY NAME: Winter Quarters Canyon Creek (Section 11 tributary)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: [illegible]

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Spruce/Aspen   Right: Aspen/Spruce

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 400 lbs/acre (right side)

BEAVER ACTIVITY: Historical use lower in this drainage

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Epilobium angustifolium*	*Agrostis stolonifera*
Populus tremuloides		*Equisetum arvense*	*Elymus canadensis*
		Geranium richardsonii	*Carex hoodii*
		Rudbeckia occidentalis	
		Senecio serra	
		Thalictrum fendleri	

POOL ATTRIBUTES

% area in pools: 75

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 0

% bank length gently sloping (>135°):

% bank length with overhanging vegetation: 5

BANK CONDITION

% bank length vegetated, stable: 10

% bank length unvegetated, stable: 0

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 90

NOTES:

1) Right side sloughing from 28' to 15'; some fallen aspen. Not sure what's happening here with the width. It went from 28 ft to 15 ft total width from 2007 to 2008. May have been a measurement error in 2007. Checked it again in 2009; it was still 15 ft. (but left marker stake was missing so we put a stake at 15 ft as indicated from the 2008 measurement).

2) Aspen had fallen into spring.

DATA SUMMARY

WQ-20: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Ranunculus cymbalaria/Equisetum arvense	1.00
TOTAL COVER (Upland Species)	10.00
TOTAL COVER (Riparian Species)	1.00
ROCK (channel)	0.00
WATER (channel)	2.00
BAREGROUND (channel)	2.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	15.00

PHOTOGRAPHIC DOCUMENTATION

WQ-20

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-21

WATERBODY NAME: Winter Quarters Canyon Creek (Section 11 tributary)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,560 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Open/Spruce/Aspen　　Right: Open to Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 800 lbs/acre

BEAVER ACTIVITY: Historical use lower in canyon.

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens	*Symphoricarpos oreophilus*	*Aster sp.*	*Agrostis stolonifera*
Populus tremuloides		*Helianthella uniflora*	*Carex hoodii*
		*Ranunculus cymbalaria**	*Elymus canadensis*

POOL ATTRIBUTES
% area in pools: 20
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 20 (Racy)

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 0
% bank length gently sloping (>135°): 50
% bank length with overhanging vegetation: 0

BANK CONDITION
% bank length vegetated, stable: 90
% bank length unvegetated, stable: 10
% bank length vegetated, unstable: 0
% bank length unvegetated, unstable: 0

NOTES:

1) Good study site - there was an obvious transition from stream riparian to upland.
2) The riparian zone here was wider than up- or down-stream.
3) Site was located in a flatter area that holds the riparian species well.
4) Total transect length measurement has decreased each year, or 37 ft (2006), 36 ft (2007), 35 ft (2008) and 32 ft (2009).
5) Logs and litter in stream (see photo).

DATA SUMMARY

WQ-21: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	4.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	8.00
Equisetum arvense	4.00
Carex hoodii	3.5
TOTAL COVER (Upland Species)	13.00
TOTAL COVER (Riparian Species)	15.50
ROCK (channel)	2.00
WATER (channel)	1.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	32.00

PHOTOGRAPHIC DOCUMENTATION

WQ-21

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-22

WATERBODY NAME: Winter Quarters Canyon Creek (Section 11 tributary)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,527 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Spruce/Aspen Right: Open to Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 800 lbs/acre

BEAVER ACTIVITY: Historical use lower in canyon

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens	*Ribes*	*Geranium richardsonii*	*Agrostis stolonifera*
Populus tremuloides		*Senecio serra*	*Carex hoodii*
		Ranunculus cymbalaria	*Elymus canadensis*
		Urtica dioica	*Carex nebrascensis*
		Veratrum californicum	*Juncus longistylis*

POOL ATTRIBUTES

% area in pools: 40

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 0

% bank length gently sloping (>135°): 50

% bank length with overhanging vegetation: 5

BANK CONDITION

% bank length vegetated, stable: 90 on left; 10 or right side; average 50.

% bank length unvegetated, stable: 5

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

NOTES:

1) There was a wide riparian area on the left side.
2) It was difficult to tell where the stream water or the hillside water influenced the riparian plants, but I thought the stream had most influence in the area where the riparian cover approached 100%. On the left side, this was an area of about 11' (refer to data).
3) There were riparian spp. at higher elevations where I considered it was more upland.
4) Right side vegetation was disturbed (taken out) by a slide.
5) Mud slide took the stake on the right side. We placed a new one in 2009 at the 11 ft distance.
6) Beware: We were attached by wasps from a gray hanging hive at this site in 2008. It was not seen in 2009.

DATA SUMMARY

WQ-22: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	21.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	9.00
TOTAL COVER (Upland Species)	30.00
TOTAL COVER (Riparian Species)	9.00
ROCK (channel)	1.00
WATER (channel)	1.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	41.00

PHOTOGRAPHIC DOCUMENTATION

WQ-22

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-23

WATERBODY NAME: Winter Quarters Canyon Creek (Section 11 tributary)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,481 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Spruce/Fir Right: Open to Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 500 lbs/acre

BEAVER ACTIVITY: Historical use lower in canyon

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Equisetum arvense*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	*Carex hoodii*
		Ranunculus cymbalaria	*Elymus canadensis*
		Senecio serra	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 0
% bank length gently sloping (>135°): 10
% bank length with overhanging vegetation: 10

BANK CONDITION

% bank length vegetated, stable: 85

% bank length unvegetated, stable: 15

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

NOTES:

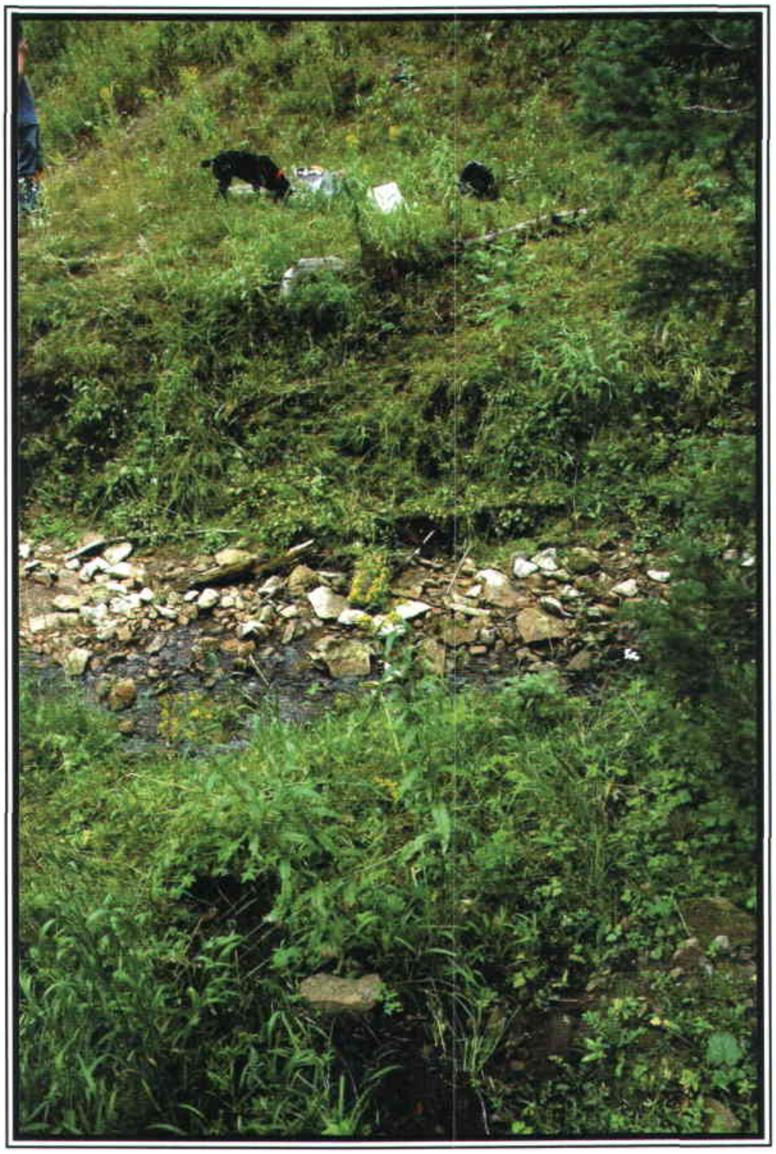
1) On the left side, the upper 3 ft of the riparian zone may be influenced by hillside and stream water.

DATA SUMMARY

WQ-23: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	6.00
	8.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	4.50
Ranunculus cymbalaria/Equisetum arvense	6.00
TOTAL COVER (Upland Species)	14.00
TOTAL COVER (Riparian Species)	10.50
ROCK (channel)	2.00
WATER (channel)	3.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	30.00

PHOTOGRAPHIC DOCUMENTATION



WQ-23

RIPARIAN COMPLEX DATA SHEET
AUGUST 2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-35

WATERBODY NAME: Winter Quarters Canyon Creek

LOCATION: Southern Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: north

STREAM GRADIENT: 1-2 ^{O}

ELEVATION: ~8478 ft.

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Aspen

Right: Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 100

BEAVER ACTIVITY: none

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens	*Ribes sp.*	*Achillea millefolium*	*Agrostis stolonifera*
		Delphinium barbeyi	
		Equisetum arvense	
		Geranium richarsonii	
		Helianthella uniflora	
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	
		Senecio serra	

POOL ATTRIBUTES
% area in pools: 50
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 25 (herbaceous)

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 50
% bank length gently sloping (>135°): 50
% bank length with overhanging vegetation: 25

BANK CONDITION
% bank length vegetated, stable: 75
% bank length unvegetated, stable: 13
% bank length vegetated, unstable: 0
% bank length unvegetated, unstable: 12

NOTES:

1) New sample site in 2008 year.
2) Good flat riparian community to monitor on the right site.

DATA SUMMARY

WQ-35: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)	
UPLAND VEGETATION	
	10.00
	13.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	22.00
TOTAL COVER (Upland Species)	23.00
TOTAL COVER (Riparian Species)	22.00
ROCK (channel)	3.50
WATER (channel)	0.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	49.00

PHOTOGRAPHIC DOCUMENTATION

WQ-35

RIPARIAN COMPLEX DATA SHEET
AUGUST 2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-36

WATERBODY NAME: Winter Quarters Canyon Creek

LOCATION: Southern Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: north

STREAM GRADIENT: 1-2 ^{o}

ELEVATION: 8475 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Conifer Right: Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 600

BEAVER ACTIVITY: no

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
		Delphinium barberi	*Elymus canadensis*
		Geranium richardsonii	
		Mimulus guttatus	
		Nasturium officinale	
		Ranunculus cymbalaria	
		Senecio serra	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 5

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 25

% bank length gently sloping (>135°): 75

% bank length with overhanging vegetation: 50 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 90

% bank length unvegetated, stable: 0

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 10

NOTES:

1) This was a new site for 2008 monitoring.
2) There was an especially good riparian community on the left side for monitoring.
3) This sample site was somewhat more than the prescribed distance from the last monitoring station because a spring would have made the appropriate distance difficult to accurately monitor. That said, even in this area there could have been some hillside water influence to the riparian community. I would guess it about a 70% chance that this influence existed.

DATA SUMMARY

WQ-36: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)	
UPLAND VEGETATION	
	10.00
	11.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Ranunculus cymbalaria	18.00
Agrostis canadensis/Elymus canadensis	3.50
TOTAL COVER (Upland Species)	21.00
TOTAL COVER (Riparian Species)	21.50
ROCK (channel)	1.50
WATER (channel)	2.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	46.00

PHOTOGRAPHIC DOCUMENTATION

WQ-36

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-06

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,709ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Blue Spruce Right: Blue Spruce

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 800 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
		Delphinium barbeyi	*Bromus carinatus*
		Geranium richardsonii	
		Mimulus guttatus	
		Osmorhiza obtusa	
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 50

% bank length gently sloping (>135°): 10

% bank length with overhanging vegetation: 80 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 85

% bank length unvegetated, stable: 0

% bank length vegetated, unstable: 10

% bank length unvegetated, unstable: 5

NOTES:

1) Good supply of water this year

2) The right bank of this site was steep and moisture from the bank may also influence the riparian vegetation.

3) The riparian species on the banks were well defined on left visually.

4) The right stake was missing so we re-staked it using the 2008 measured transect distance (32 ft).

DATA SUMMARY

WQ-06: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Geranium richardsonii	6.00
Agrostis stolonifera	2.00
Ranunculus cymbalaria	1.00
TOTAL COVER (Upland Species)	20.00
TOTAL COVER (Riparian Species)	9.00
ROCK (channel)	0.00
WATER (channel)	3.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	32.00

PHOTOGRAPHIC DOCUMENTATION

WQ-06

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-24

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,737 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Grass/Forb (Ruoc) Right: Grass/Forb (Ruoc)

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 600 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	*Elymus canadensis*
		Mimulus guttatus	
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	
		Senecio serra	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: no

AQUATIC VEGETATION

% streambed with filamentous algae: no

% stream margin with rooted aquatic: no

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 50

% bank length gently sloping (>135°): 0

% bank length with overhanging vegetation: 100 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 85

% bank length unvegetated, stable: 5

% bank length vegetated, unstable: 15

% bank length unvegetated, unstable: 0

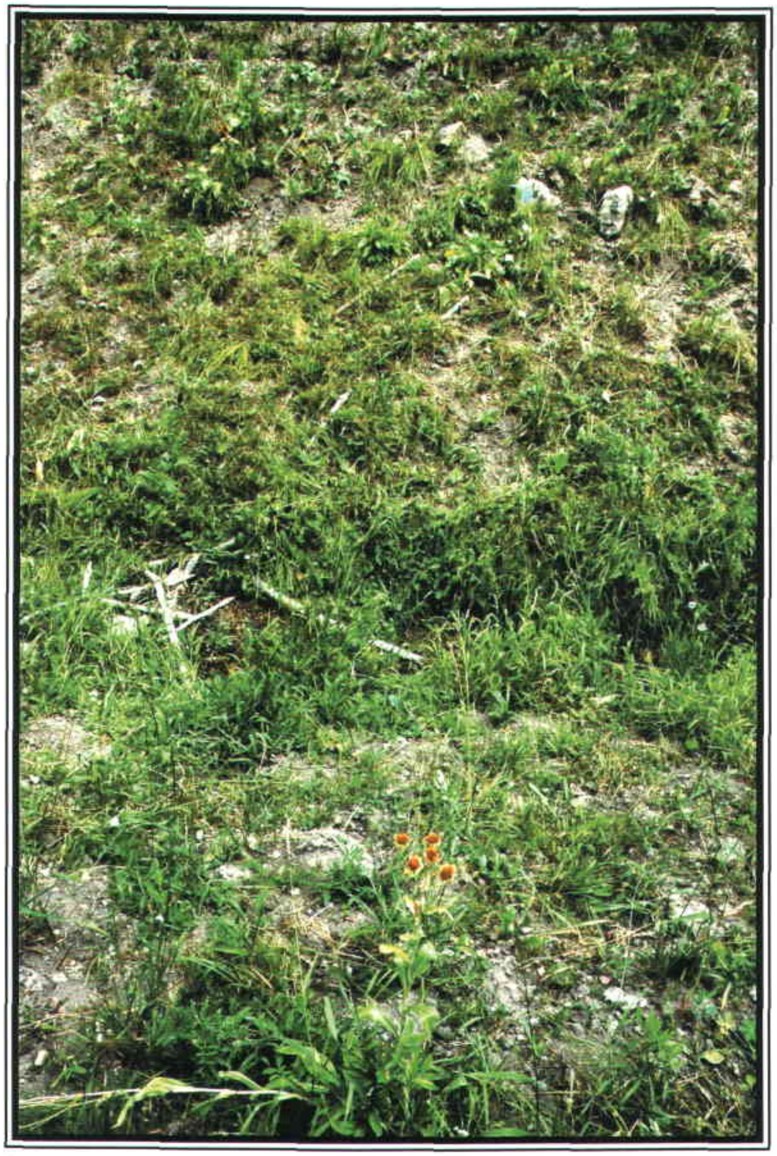
NOTES:

DATA SUMMARY

WQ-24: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Elymus canadensis	2.00
Agrostis stolonifera	2.00
TOTAL COVER (Upland Species)	20.00
TOTAL COVER (Riparian Species)	4.00
ROCK (channel)	1.00
WATER (channel)	2.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	27.00

PHOTOGRAPHIC DOCUMENTATION



WQ-24

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-25

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,783 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Spruce/Fir/Aspen Right: Spruce/Fir/Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 800 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Abies lasiocarpa	*Ribes sp.*	*Geranium richardsonii*	*Agrostis stolonifera*
Picea pungens		*Osmorhiza obtusa*	*Elymus spicatus*
Populus tremuloides		*Ranunculus cymbalaria*	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: Some rooted Racy

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 10

% bank length gently sloping (>135°): 30

% bank length with overhanging vegetation: 100 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 90

% bank length unvegetated, stable: 10

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

NOTES:

1) Good, well-defined river channel.

2) Bank slope increases abruptly. Therefore riparian habitat on right.

DATA SUMMARY

WQ-25: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	11.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Geranium richardsonii	6.00
Agrostis stolonifera/Ranunculus cymbalaria	2.50
TOTAL COVER (Upland Species)	20.00
TOTAL COVER (Riparian Species)	8.50
ROCK (channel)	0.00
WATER (channel)	0.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	29.00

PHOTOGRAPHIC DOCUMENTATION

WQ-25

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-26

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,804 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Blue Spruce Right: Grass/Forb

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 600 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Aster sp.*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	*Bromus carinatus*
		Lathyrus lanszwertii	*Elymus canadensis*
		Mimulus guttatus	*Elymus spicatus*
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	
		Wyethia amplexicaulis	

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 30

% bank length gently sloping (>135°):

% bank length with overhanging vegetation: 100 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 90

% bank length unvegetated, stable: 10

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

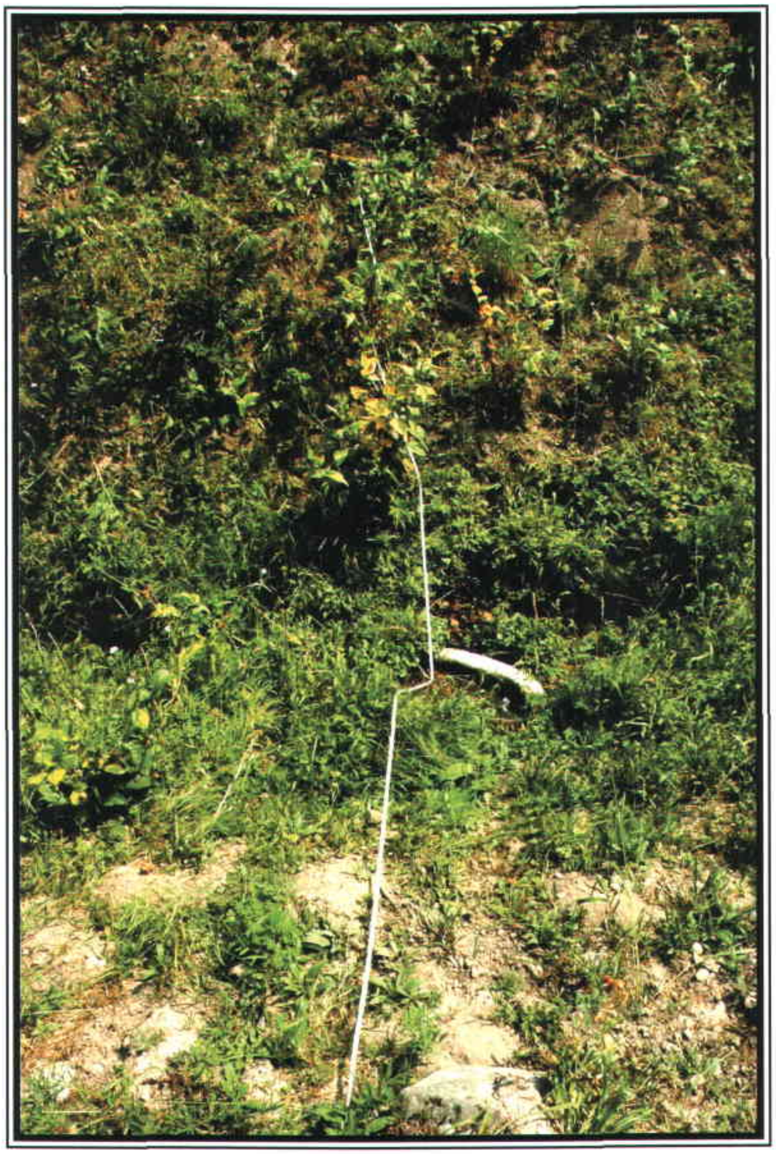
NOTES:

DATA SUMMARY

WQ-26: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	
	7.50
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Ranunculus cymbalaria	3.00
Agrostis stolonifera/Geranium richardsonii	2.50
TOTAL COVER (Upland Species)	16.50
TOTAL COVER (Riparian Species)	5.50
ROCK (channel)	1.00
WATER (channel)	1.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	24.00

PHOTOGRAPHIC DOCUMENTATION



WQ-26

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-27

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,858 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Right:

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 800 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	
		Mimulus guttatus	
		Nasturtium officinale	
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	

POOL ATTRIBUTES

% area in pools: 35

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 10 (Nasturtium officinale)

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 40

% bank length gently sloping (>135°): 30

% bank length with overhanging vegetation: 50 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 75

% bank length unvegetated, stable: 10

% bank length vegetated, unstable: 8

% bank length unvegetated, unstable: 7

NOTES:

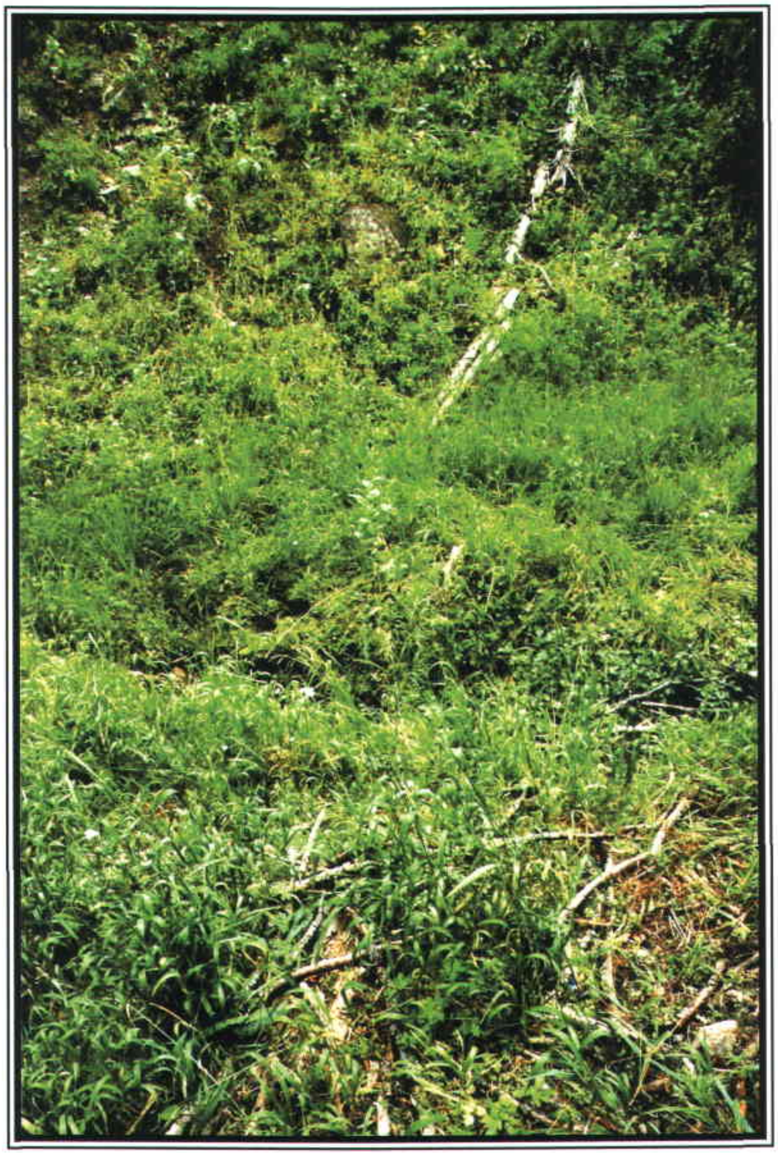
1) Good well-defined flat area with Agst on right side.

DATA SUMMARY

WQ-27: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	12.50
Agrostis stolonifera/Ranunculus cymbalaria	2.00
TOTAL COVER (Upland Species)	19.00
TOTAL COVER (Riparian Species)	14.50
ROCK (channel)	0.50
WATER (channel)	2.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	36.00

PHOTOGRAPHIC DOCUMENTATION



WQ-27

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-28

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,879 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Conifer/Aspen Right: Conifer/Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 500 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens		*Delphinium barbeyi*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	*Avena fatua*
		Osmorhiza obtusa	*Carex hoodii*
		Ranunculus cymbalaria	*Poa secunda*
		Thalictrum fendleri	
		Veratrum californicum	

POOL ATTRIBUTES
- % area in pools: 50
- % pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
- % streambed with filamentous algae: 0
- % stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG
- % bank length undercut (<90°): 50
- % bank length gently sloping (>135°): 50
- % bank length with overhanging vegetation: 75 (herbaceous)

BANK CONDITION
- % bank length vegetated, stable: 85
- % bank length unvegetated, stable: 15
- % bank length vegetated, unstable: 0
- % bank length unvegetated, unstable: 0

NOTES:

1) Good water flow, does not appear to be decreasing with elevation yet.

DATA SUMMARY

WQ-28: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	13.00
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Ranunculus cymbalaria	4.0
TOTAL COVER (Upland Species)	23.00
TOTAL COVER (Riparian Species)	4.00
ROCK (channel)	1.00
WATER (channel)	1.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	29.00

PHOTOGRAPHIC DOCUMENTATION

WQ-28

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-29

WATERBODY NAME: Winter Quarters Canyon Creek (Unnamed tributary east of Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,939 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Conifer/Aspen Right: Conifer/Aspen

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 600 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Grasses (or grasslike)
Picea pungens	*Ribes sp.*	*Osmorhiza obtusa*	*Agrostis stolonifera*
Populus tremuloides		*Rudbeckia occidentalis*	

POOL ATTRIBUTES

% area in pools: 70

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 50

% bank length gently sloping (>135°): 0

% bank length with overhanging vegetation:

BANK CONDITION

% bank length vegetated, stable: 85

% bank length unvegetated, stable: 15

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

NOTES:

1) Most of left bank was called "upland" because the redtop occurring there seemed to be more influenced by side slope moisture.

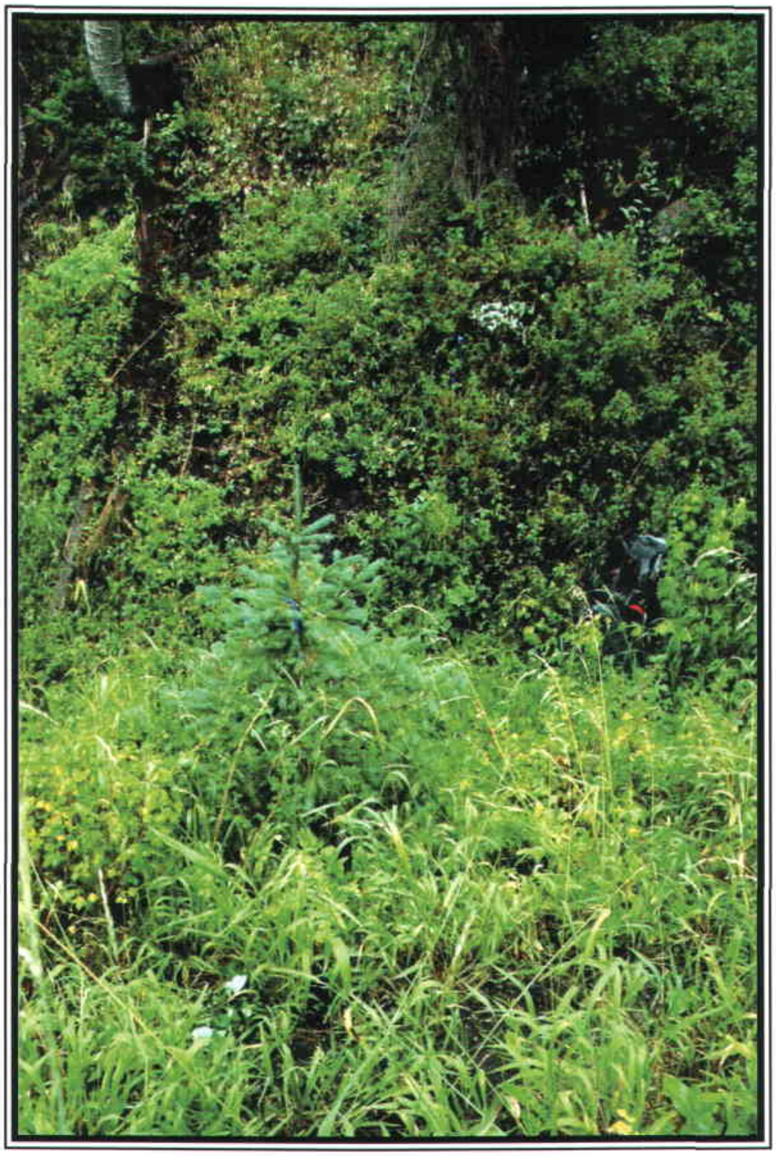
2) There was water flow at this elevation too.

DATA SUMMARY

WQ-29: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	12.00
	8.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Geranium richardsonii	2.00
Agrostis stolonifera	4.50
TOTAL COVER (Upland Species)	20.00
TOTAL COVER (Riparian Species)	6.50
ROCK (channel)	0.50
WATER (channel)	1.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	28.00

PHOTOGRAPHIC DOCUMENTATION



WQ-29

RIPARIAN COMPLEX DATA SHEET
AUGUST 2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-04

WATERBODY NAME: Winter Quarters Canyon Creek

LOCATION: Southern Wasatch Plateau, Utah; Lower Box Canyon

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: NE

STREAM GRADIENT: ~2 ^{o}

ELEVATION: 8,664 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream):

Left: Aspen/Mtn. Herbland Right: Blue Spruce/Mtn. Herbland

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 700 lbs/acre

BEAVER ACTIVITY: Historical activity a few hundred feet upstream.

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Geranium richardsonii*	*Agrostis stolonifera*
Populus tremuloides		*Lupinus sp.*	*Carex hoodii*
		Mimulus guttatus	*Elymus canadensis*
		Ranunculus cymbalaria	
		Senecio serra	
		Urtica dioica	
		Viguiera multiflora	

POOL ATTRIBUTES
- % area in pools: 50
- % pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
- % streambed with filamentous algae: 0
- % stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG
- % bank length undercut (<90°): 10
- % bank length gently sloping (>135°): 20
- % bank length with overhanging vegetation: 50 (herb.)

BANK CONDITION
- % bank length vegetated, stable: 90
- % bank length unvegetated, stable: 10
- % bank length vegetated, unstable: 0
- % bank length unvegetated, unstable: 0

NOTES:

1) This site is approx. midway between main channel and upper Box Canyon sample point.
2) Not sure why there's more riparian width here compared to 2005.
3) Left stake was displaced. We re-staked this side using last years' measured transect distance (27 ft).

DATA SUMMARY

WQ04: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)

UPLAND VEGETATION	
	9.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Geranium richardsonii	5.50
TOTAL COVER (Upland Species)	18.00
TOTAL COVER (Riparian Species)	5.50
ROCK (channel)	1.00
WATER (channel)	2.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	27.00

PHOTOGRAPHIC DOCUMENTATION

WQ-04

RIPARIAN COMPLEX DATA SHEET
AUGUST 2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-34

WATERBODY NAME: Winter Quarters Canyon Creek; upper Box Canyon

LOCATION: Southern Wasatch Plateau, Utah; upper Box Canyon

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: ENE

STREAM GRADIENT: 2^{o}

ELEVATION: 8,729 ft.

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Mtn. Herbland/Conifer Right: Mtn. Herbland/Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 1000 lbs./acre

BEAVER ACTIVITY: see Notes

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Abies lasiocarpa	*Ribes sp.*	*Geranium richardsonii*	*Agrostis stolonifera*
			Carex nebrascensis
			Elymus canadensis

POOL ATTRIBUTES

% area in pools: 80

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 40

% bank length gently sloping (>135°): 0

% bank length with overhanging vegetation: 90 (herbaceous)

BANK CONDITION

% bank length vegetated, stable: 80

% bank length unvegetated, stable: 8

% bank length vegetated, unstable: 5

% bank length unvegetated, unstable: 7

NOTES:

1) This site was a new sample station in 2008.

2) Left side riparian community was sloughing, perhaps from animal use.

DATA SUMMARY

WQ-04: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)	
UPLAND VEGETATION	
	10.50
	12.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera/Geranium richardsonii	8.00
TOTAL COVER (Upland Species)	22.50
TOTAL COVER (Riparian Species)	8.00
ROCK (channel)	0.00
WATER (channel)	2.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	33.00

PHOTOGRAPHIC DOCUMENTATION

WQ-34

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: NumberWQ-03

WATERBODY NAME: Winter Quarters Canyon Creek; upper Box Canyon

LOCATION: Southern Wasatch Plateau, Utah; upper Box Canyon

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: ENE

STREAM GRADIENT: 2^{o}

ELEVATION: 8,729 ft.

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Mtn. Herbland Right: Mtn. Herbland

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Increasing

ESTIMATED FORAGE PRODUCTION: 1500 lbs./acre

BEAVER ACTIVITY: see Notes

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Achillea millefolium*	*Agrostis stolonifera*
Populus tremuloides		*Helianthella uniflora*	*Carex nebrascensis*
		Senecio serra	*Carex hoodii*
		Viguiera multiflora	*Juncus longistylis*

POOL ATTRIBUTES

% area in pools: 50

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 50 (much of the stream had rooted vegetation)

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 30

% bank length gently sloping (>135°): 0

% bank length with overhanging vegetation: 95

BANK CONDITION

% bank length vegetated, stable: 95

% bank length unvegetated, stable: 5

% bank length vegetated, unstable: 0

% bank length unvegetated, unstable: 0

NOTES:

1) This site was approx. 400 ft upstream frm a very old beaver dam.
2) There was very little water at the site - about 12 inches wide.
3) This site's elev. may be too high to always observe water. This appears to be a fair water year; there may be no water here in lower prec. years.
4) The adjacent areas were open areas (Mtn. Herblands)

DATA SUMMARY

WQ-03: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)

UPLAND VEGETATION	
	19.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	11.50
TOTAL COVER (Upland Species)	19.00
TOTAL COVER (Riparian Species)	11.50
ROCK (channel)	0.00
WATER (channel)	0.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	31.00

PHOTOGRAPHIC DOCUMENTATION

WQ-03

RIPARIAN COMPLEX DATA SHEET
AUGUST 2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-33

WATERBODY NAME: Winter Quarters Canyon Creek

LOCATION: Southern Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: N

STREAM GRADIENT: 1-2 ^{o}

ELEVATION: 8769 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Mtn Grassland/Conifer   Right: Mtn Grassland/Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types):

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 500 lbs./ac

BEAVER ACTIVITY: Several beaver ponds located below this site.

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens	*Symphoricarpos oreophilus*	*Achillea millefolium*	*Agrostis stolonifera*
Populus tremuloides		*Lupinus sp.*	*Elymus canadensis*
Sambucus caerulea		*Rudbeckia occidentalis*	
		Taraxacum officinale	

POOL ATTRIBUTES
% area in pools: 100
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 30
% bank length gently sloping (>135°): 20
% bank length with overhanging vegetation: 20 (herbaceous)

BANK CONDITION
% bank length vegetated, stable: 75
% bank length unvegetated, stable: 20
% bank length vegetated, unstable: 3
% bank length unvegetated, unstable: 2

NOTES:

1) This is a new sample location for 2008.
2) There was lots of beaver influence below this site.

DATA SUMMARY

WQ- 33: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)	
UPLAND VEGETATION	
	14.00
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Agrostis stolonifera	2.50
Carex nebrascensis	2.00
TOTAL COVER (Upland Species)	24.00
TOTAL COVER (Riparian Species)	4.50
ROCK (channel)	0.00
WATER (channel)	4.50
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	33.00

PHOTOGRAPHIC DOCUMENTATION

WQ-33

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-30

WATERBODY NAME: Winter Quarters Canyon Creek (Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: ENE

STREAM GRADIENT: 1-3°

ELEVATION: 8,856 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Aspen/Conifer   Right: Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 1000 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens	*Ribes sp.*	*Geranium richardsonii*	*Agrostis stolonifera*
Populus tremuloides		*Helianthella uniflora*	*Carex hoodii*
		Lathyrus lanszwertii	*Elymus canadensis*
		Ranunculus cymbalaria	
		Urtica dioica	

POOL ATTRIBUTES
- % area in pools: 70
- % pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
- % streambed with filamentous algae: 0
- % stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG
- % bank length undercut (<90°): 60
- % bank length gently sloping (>135°): 10
- % bank length with overhanging vegetation: 95(shrubs & herbs)

BANK CONDITION
- % bank length vegetated, stable: 80
- % bank length unvegetated, stable: 20
- % bank length vegetated, unstable: 0
- % bank length unvegetated, unstable: 0

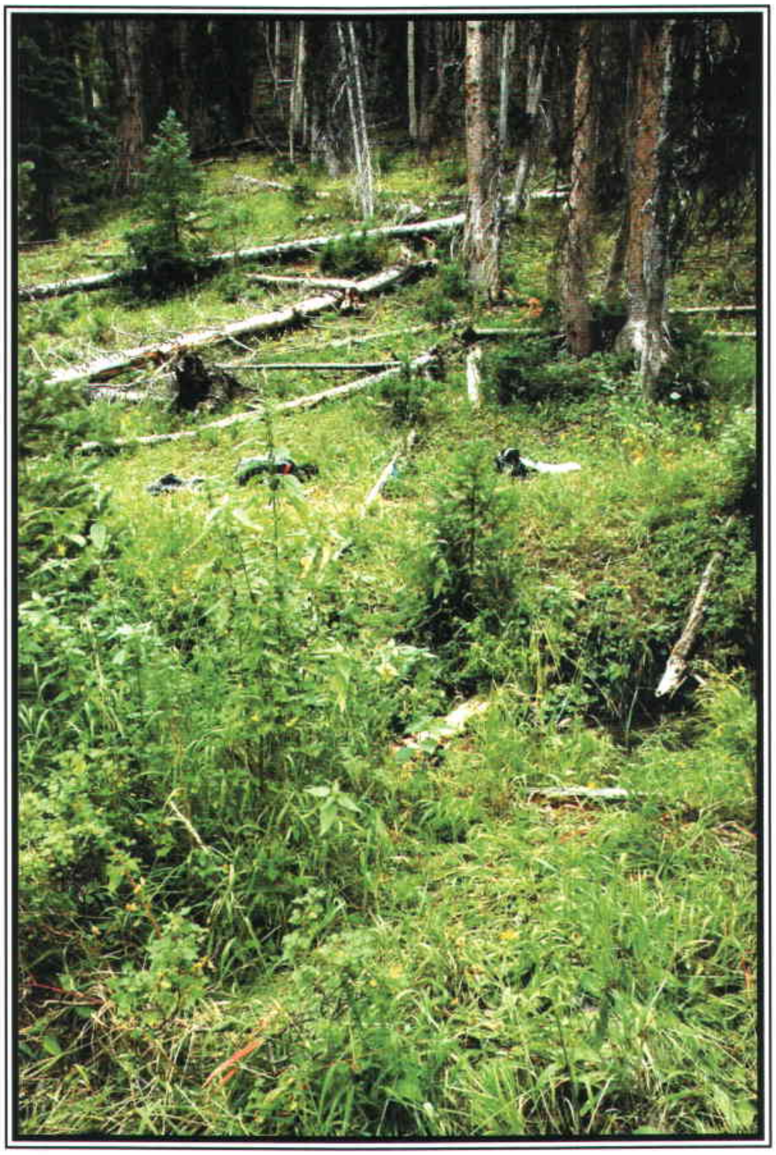
NOTES:

DATA SUMMARY

WQ-30 Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	6.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Elymus canadensis/Urtica dioica	3.00
Agrostis stolonifera/Geranium richardsonii	5.50
TOTAL COVER (Upland Species)	16.00
TOTAL COVER (Riparian Species)	8.50
ROCK (channel)	0.00
WATER (channel)	2.50
BAREGROUND (channel)	1.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	28.00

PHOTOGRAPHIC DOCUMENTATION



WQ-30

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-31

WATERBODY NAME: Winter Quarters Canyon Creek (Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: ENE

STREAM GRADIENT: 1-3 ^{o}

ELEVATION: 8,868 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Aspen Right: Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 400 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Abies lasiocarpa	*Symphoricarpos oreophilus*	*Arnica cordifolia*	*Agrostis stolonifera*
Picea pungens		*Equisetum arvensis*	*Calamagrostis canadensis*
Populus tremuloides		*Geranium richardsonii*	*Juncus longistylis*
		Ranunculus cymbalaria	
		Rudbeckia occidentalis	

POOL ATTRIBUTES
% area in pools: 50
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic:0

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 100
% bank length gently sloping (>135°): 0
% bank length with overhanging vegetation:0

BANK CONDITION
% bank length vegetated, stable: 80
% bank length unvegetated, stable: 10
% bank length vegetated, unstable: 0
% bank length unvegetated, unstable: 10

NOTES:

1) This was a good sample site because the riparian and upland zones were obvious.
2) There was no ambiguity about what water was influencing the riparian zone - it was the stream water, not the side-slope ground moisture.
3) Not mentioned previous years, but the left slope appeared unstable.

DATA SUMMARY

WQ-31: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	9.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Carex nebrascensis	4.00
TOTAL COVER (Upland Species)	19.00
TOTAL COVER (Riparian Species)	4.00
ROCK (channel)	0.00
WATER (channel)	2.00
BAREGROUND (channel)	1.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	26.00

PHOTOGRAPHIC DOCUMENTATION

WQ-31

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-32

WATERBODY NAME: Winter Quarters Canyon Creek (Box Canyon)

LOCATION: Wasatch Plateau, Utah

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins, S. Vlietstra[2]

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: ENE

STREAM GRADIENT: 1-3 ^{O}

ELEVATION: 8,870 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Grass/Forb Right: Aspen/Conifer

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Stable

ESTIMATED FORAGE PRODUCTION: 1000 lbs/acre

BEAVER ACTIVITY: No

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens		*Equisetum arvensis*	*Agrostis stolonifera*
Populus tremuloides		*Geranium richardsonii*	*Elymus canadensis*
		Mimulus guttatus	
		Rudbeckia occidentalis	
		Viguiera multiflora	

POOL ATTRIBUTES
% area in pools: 50
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 0
% bank length gently sloping (>135°): 0
% bank length with overhanging vegetation: 100 (herbaceous)

BANK CONDITION
% bank length vegetated, stable: 100
% bank length unvegetated, stable: 0
% bank length vegetated, unstable: 0
% bank length unvegetated, unstable: 0

NOTES:

1) Good well-defined riparian zone.
2) Good water flow; flow also continues from upper canyon reaches.
3) It was thought that the riparian zone and sampling locations were well-represented in Box Canyon, so more sampling upstream was not done.

DATA SUMMARY

WQ-32: Cover by community types in Winter Quarters Canyon (2009).

UPLAND VEGETATION	Cover (ft)
	10.00
	10.50
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Carex nebrascensis	7.00
Elymus canadensis	2.50
TOTAL COVER (Upland Species)	20.50
TOTAL COVER (Riparian Species)	9.50
`ROCK (channel)	0.00
WATER (channel)	2.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	32.00

PHOTOGRAPHIC DOCUMENTATION

WQ-32

RIPARIAN COMPLEX DATA SHEET
2009

CLIENT: Canyon Fuel Company, Skyline Mines

COMPLEX: Number WQ-02

WATERBODY NAME: Winter Quarters Canyon Creek

LOCATION: Southern Wasatch Plateau, Utah; Bob's Canyon

DATE: August 29 - September 3, 2009

OBSERVER(S): P.D. Collins' S.Vlietstra

QUAD NAME: Scofield, Utah

GEOLOGIC PARENT MATERIAL: Blackhawk Formation

STEAM ASPECT: E

STREAM GRADIENT: ~2 ^{o}

ELEVATION: 8,619 ft

SIZE OF COMPLEX: (see quantitative data)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Snowberry Right: Spruce/Fir

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex
(refer to quantitative data results for this information)	

SUCCESSIONAL STATUS: Climax

APPARENT FORAGE TREND: Increasing

ESTIMATED FORAGE PRODUCTION: 500 lbs./acre

BEAVER ACTIVITY: no

PHOTOGRAPH TAKEN: Yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing, hunting, recreation.

SPECIES OBSERVED:

Trees	**Shrubs**	**Forbs**	**Grasses (or grasslike)**
Picea pungens	*Rosa woodsii*	*Carduus nutans*	*Agrostis stolonifera*
Populus tremuloides		*Equisetum arvense*	*Bromus japonicus*
		Geranium richardsonii	*Carex hoodii*
		Helianthella uniflora	*Elymus canadensis*
		Lupinus argenteus	
		Rubus idaeus	
		Rudbeckia occidentalis	
		Urtica dioica	

POOL ATTRIBUTES

% area in pools: 20

% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0

% stream margin with rooted aquatic: 0

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 50

% bank length gently sloping (>135°): 20

% bank length with overhanging vegetation: 10

BANK CONDITION

% bank length vegetated, stable: 65

% bank length unvegetated, stable: 15

% bank length vegetated, unstable: 10

% bank length unvegetated, unstable: 10

NOTES:

1) The right side had a bench that supported some riparian species, but it was probably due to hillside moisture, not the stream directly.
2) The riparian area measured was well defined below the right bench and left hillside.
3) We found the right stake, but not the left. We re-staked it at the previous measured length of (28 ft).
4) On the left side there was not much living cover; it was not stable on that side either.

DATA SUMMARY

WQ-02: Cover by community types in Winter Quarters Canyon (2009).

USDA Forest Service Protocol (1992)	
UPLAND VEGETATION	
	10.00
	10.00
RIPARIAN VEGETATION	
Dominant Woody Species	
Dominant Herbaceous Species	
Equisetum arvense	1.50
Agrostis stolonifera/Equisetum arvense	2.00
TOTAL COVER (Upland Species)	20.00
TOTAL COVER (Riparian Species)	3.50
ROCK (channel)	1.5
WATER (channel)	3.00
BAREGROUND (channel)	0.00
LITTER	0.00
MOSS	0.00
TOTAL COVER	28.00

PHOTOGRAPHIC DOCUMENTATION

WQ-02

Vegetation Monitoring at the Conveyor Bench: Treatment Area No. 3

at the
Skyline Mine
Carbon County,
Utah

Prepared by

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by

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for

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December 2009

Table of Contents

Introduction

Revegetation techniques have been implemented on the disturbed areas created by construction of a coal conveyor system at the Skyline Mine in Carbon County, Utah. Based on reviewing a document called *Conveyor Bench Revegetation Plan Information Provided by Soil Conservation Service* (August 19, 1988), the following brief history has been provided.

The coal conveyor system was constructed in the mid-1980s. Cut and fill slopes were created during this construction. Slope angles varied, but were generally quite steep and range from 50% to 120%. Attempts were initially made with little success to control erosion and sloughing of these slopes by implementing a variety of revegetation techniques including hydroseeding, hydromulching and applications of jute netting for stabilization. These techniques provided varying degrees of success ranging from poor to fair. Therefore, recommendations were made in 1988 by the Soil Conservation Service (SCS), now called the Natural Resources Conservation Service (NRCS), to test different reclamation treatments (called **practices** in that document) on a variety of disturbed areas adjacent to the conveyor.

A letter-report with a summary of these findings was submitted to Canyon Fuel on May 13, 2009. This document, however, reports all findings of quantitatively sampling the vegetation in a specific area of the coal conveyor system called **Treatment Area No. 3**. The data should determine whether or not the existing vegetation has reached the target cover value that was pre-determined as a revegetation success standard while the conveyor remains in operation.

The location and boundary of Treatment Area No. 3 can be seen in the aforementioned SCS document. Although several other *practices* were conducted in this area from 1988 through 1991, a progress report in 1992 states that only two *practices* were to be continued in Treatment Area No. 3; these *practices* included annual supplemental broadcast seeding and fertilization. It appears much of the previous evaluations of revegetation success was made from qualitative rather than quantitative data, and success criteria were unclear. However, one statement in the SCS document states that a given treatment would be conducted *"as needed to reach target cover of 20%"* (page 4). This author (and G. Galecki from the Skyline Mine in an email communication dated 11 May 2009) assumed this value was the standard set for revegetation success. Quantitative data reported herein have been compared to that value as the measure of success.

Methods

Methodologies used for this study were performed in accordance with the guidelines provided by the State of Utah, Division of Oil, Gas and Mining (DOGM) and other appropriate sources. The field work for the quantitative and qualitative data were recorded within the plant communities in September 2008.

Quadrat Placement

Regular points for sampling the vegetation were placed within the boundaries of the Treatment

Area No. 3. Once the points were established, quadrat locations for sampling were chosen using random numbers from the points for the entire length of the treatment area.

Cover estimates were made using ocular methods with meter square quadrats. Species composition, cover by species, and relative frequencies were also assessed from the quadrats. Additional information field notes were recorded on the raw data sheets. Plant nomenclature follows "A Utah Flora" (Welsh et al., 2003).

Sampling adequacy for cover was attempted by using the formula given below.

$$nMIN = \frac{t^2 s^2}{(dx)^2}$$

where,

nMIN	= minimum adequate sample
t	= appropriate confidence t-value
s	= standard deviation
x	= sample mean
d	= desired change from mean

With the values used for "t" and "d"above, the goal was to meet sample adequacy with 80% confidence within a 10% deviation from the true mean.

Color photographs of the sample areas were taken at the time of sampling and have been submitted with this report.

Results

Results of the quantitative sampling the vegetation indicated the total living cover to be 54.25% (Table 1-A). The living cover was comprised of 87.30% grasses, 10.24% forbs and 2.46% shrubs (Table 1-B). Additionally, the living cover was comprised of "desirable" plant species with not "weedy" or exotic species in the sample quadrats (Table 2). The most common species by cover and frequency were smooth brome (*Bromus inermis*), Western wheatgrass *(Elymus smithii*), and Kentucky bluegrass (*Poa pratensis*); Table 2 lists all plant species found in the quadrats and includes their cover and relative frequency values. Color photographs showing the sample areas are shown on Figures 1 and 2.

Discussion

If the 20% cover value is used for the revegetation success standard, the 54.25% cover value found in Treatment Area No. 3 clearly meets the revegetation objective. Additionally, the cover of the revegetated area was comprised of desirable and not weedy plant species.

The pre-determined cover value of 20% was most likely thought to be high enough that, when added to cover by litter and rock, it should adequately control erosion for the life of the conveyor, or adequate for "interim revegetation". The cover value achieved during this sample period, however, may even approach a respectable value for "final revegetation" success. Final revegetation success standards are generally chosen by comparing parameters from adjacent, undisturbed, native plant communities in the area.

Table 1: Skyline Mine Conveyor Bench Revegetation Project. Total cover and standard deviation (2008).

Treatment Area No. 3 n=40	Mean Percent	Standard Deviation
A. TOTAL COVER		
Living Cover	54.25	13.16
Litter	14.40	6.50
Bareground	16.78	10.72
Rock	14.58	9.10
B. % COMPOSITION		
Trees & Shrubs	2.46	9.13
Forbs	10.24	17.75
Grasses	87.30	18.65

Table 2: Skyline Mine Conveyor Bench Revegetation Project. Cover, standard deviation and frequency by species (2008).

			n=40
Treatment Area No. 3	**Mean Percent**	**Standard Deviation**	**Relative Frequency**
TREES & SHRUBS			
Artemisia tridentata	0.38	2.34	2.50
Rosa woodsii	0.25	1.56	2.50
Symphoricarpos oreophilus	0.38	2.34	2.50
FORBS			
Astragalus cicer	3.63	9.87	20.00
Geranium richardsonii	0.13	0.78	2.50
Linum lewisii	0.13	0.78	2.50
Machaeranthera canescens	1.50	4.06	15.00
Penstemon strictus	0.38	1.73	5.00
GRASSES			
Bromus carinatus	16.50	19.34	65.00
Dactylis glomeratus	0.25	1.56	2.50
Elymus lanceolatus	4.50	10.23	20.00
Elymus smithii	14.75	16.62	57.50
Poa pratensis	11.13	13.81	45.00
Stipa hymenoides	0.38	2.34	2.50

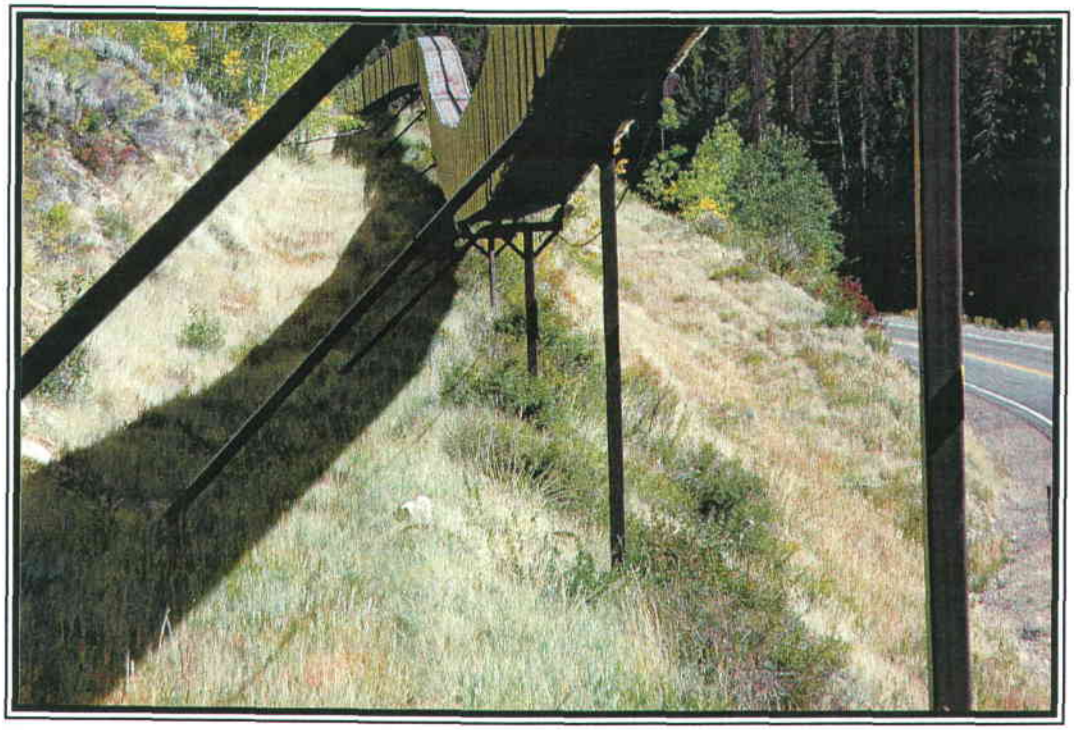

Figure 1

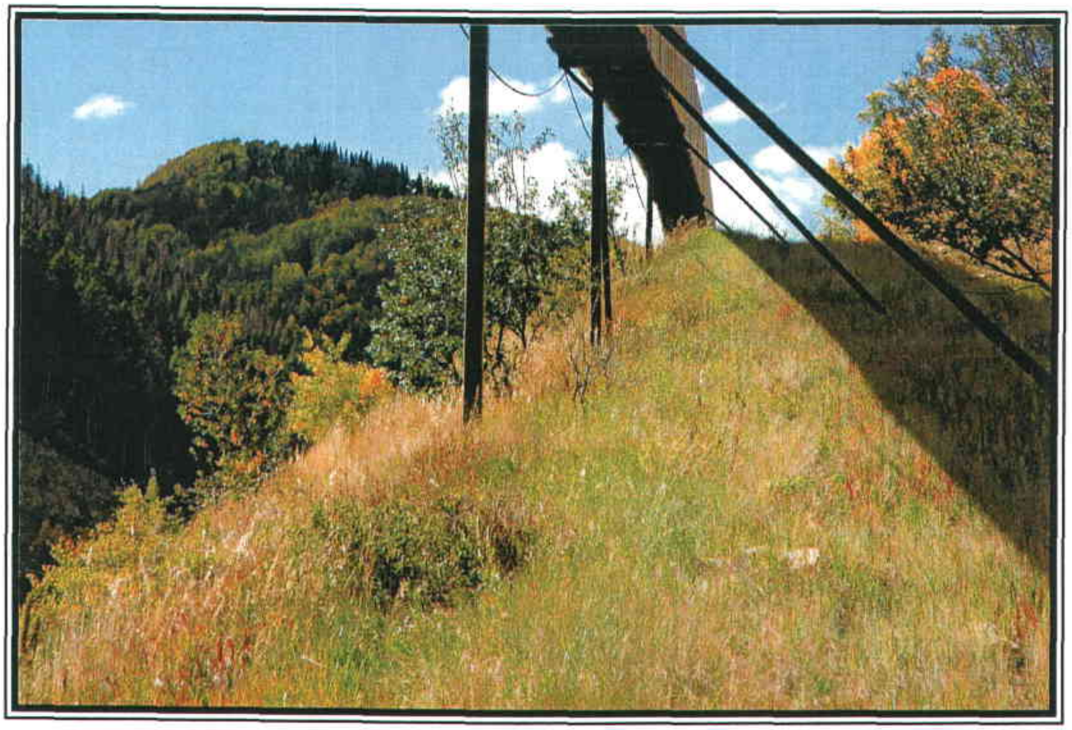

Figure 2

AN ASSESSMENT OF THE MACROINVERTEBRATES OF JAMES CANYON CREEK & BURNOUT CREEK

in

September 2007 & July 2008

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March 2010

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Introduction

James Canyon Creek and Burnout Creek of the Huntington Creek Drainage Basin, Emery County, Utah, are located in an area subject to subsidence due to coal mining activities. Both streams have been monitored since the fall, of 2000 to document any changes that may be associated with subsidence in their watersheds.

This report will cover samples taken up to July 2008. The July 2008 samples represent the tenth set of benthic invertebrate samples taken at James Canyon Creek and the ninth set that has been taken at Burnout Creek.

Methods

Quantitative samples were taken with a modified box sampler (Shiozawa 1986) having a capture net constructed of 253 micron-mesh Nitex screen. Three samples were taken at both James Canyon Creek and Burnout Creek, as prescribed to Canyon Fuels Corporation by the Utah Division of Wildlife Resources. The samples were field preserved with ethyl alcohol and were returned to the laboratory for processing. Samples were sorted in a backlit illuminated pan. Organisms were identified to the lowest taxonomic unit possible. Small specimens and those of questionable identity were examined under magnification. After the sample had been sorted with the unaided eye and visible invertebrates removed, the remaining material was subsampled and examined under magnification to insure that accurate counts of the early instars were included. Identification was based on the keys of Merritt and Cummins (2008). The mean counts for each taxon were used to determine the density per square meter. Standing crop was estimated from wet weights of total invertebrates collected at each station.

The USFS Biotic Condition Index (Winget and Mangum 1979) was calculated with the community tolerance quotient (CTQa) and the predicted community tolerance quotient (CTQp). CTQp estimates were based on water chemistry data and physical data applied as prescribed in Winget (1972) to the Huntington Creek drainage, and both streams had CTQp values of 80. Diversity was calculated using the Shannon-Weiner index (Pielou 1977). Cluster analysis was run with NTSYS-pc, using the Bray-Curtis dissimilarity index with the UPGMA clustering algorithm. Data from all sampling periods (fall, 2000 through spring, 2008) for both Burnout Creek and James Canyon Creek have been included in the cluster analysis.

Table 1. Sampling station locations

Canyon	GPS coordinates	Elevation
James	N 39°38.033' W 111° 13.739'	8627 ft
Burnout	N 39° 38.929' W 111° 14.171'	8613 ft

Results and Discussion

Biological Characterization

Number of Taxa

The Burnout Creek sample site showed a decrease in number of taxa in fall 2007, while the spring 2008 samples had an increase in number of taxa. The fall sample for Burnout Creek had 22 sample taxa. In comparison to the fall 2003 sample, this was a 15% decrease in the number of taxa. The fall 2007 sample recorded the lowest number of taxa collected during any previous fall season, but equaled the number of spring, 2004 taxa. The spring 2008 sample set contained 28 different taxa (Table 2). This was six greater than collected in the spring 2004 sample, a 27% increase. The number of taxa in the spring, 2008 series was equal to the long term site average of 28.

The fall 2007 and spring 2008 Burnout creek samples contained taxa not previously recorded. Three newly recorded taxa were found in the fall 2007 Burnout samples: Coeleopteran families Dyropidae, Dyticidae and Molluscan family Physidae. Six new taxa were found in spring 2008 Burnout Creek samples: Diptera; *Dixa, Neòplasta,* and *Rhabdomastix*; Plecoptera; *Paraperla* and Coleoptera; Dytiscidae and Staphylinidae.

The James Canyon Creek samples for the fall 2007 and spring 2008 periods decreased in number of taxa. The September 2007 sample for James Canyon Creek had 26 taxa, a 4% decrease from the fall, 2003 sample. The July 2008 James Canyon Creek spring sample contained 23 taxa (Table 2). This was a 21% decrease from the spring, 2004 samples. The low number of taxa recorded in the spring 2008 sample, is equal to the number of taxa recorded in spring, 2003. The spring 2008 sample had 5 fewer taxa than the long term average of 28. Two new taxa were found in the fall 2007 and spring 2008 James Canyon Creek samples; Diptera -*Clinocera* and *Neoplasta*

Table 2. Number of Taxa collected from Burnout and James Canyon Creeks

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2007	Spring 2008
Burnout Creek	33	34	27	30	-	23	26	22	22	28
James Canyon Creek	31	35	30	27	24	23	27	29	26	23

Total Densities

Burnout Canyon Creek recorded a large decrease in total density in the 2007 fall samples, but densities increased in the spring 2008 samples. The fall density estimate was13,281 per square meter, just 24% of the fall 2003 sample series and about 1000 individuals above the low fall density collected in the fall of 2000. The spring 2008 density estimate of 26,290 per square meter was a 17% increase over the spring, 2004 sample series (Table 3). This falls within the expected range based on the 2000-2004 spring sampling periods. However, the overall density for spring samples is still higher than the 2008 spring sample. The difference may be influenced by the reproductive cycles of the dominant organisms in Burnout Creek. Many aquatic insects reproduce in the summer and high numbers of small, early instar offspring are found in fall samples. By the next spring many of these have grown, and are easily seen during sorting. High water in the spring of 2003 delayed sampling until July, a month later than usual. This would have allowed an additional month of mortality for the invertebrates and emergences may have also been underway. Both factors would result in decreased densities.

James Canyon Creek densities decreased for both the fall 2007 and spring 2008 sample series. In fall, 2007 the total density was 33,431 per square meter. This was 31% of the fall, 2003 sample series. The spring 2008 sample series recorded 18,079 organisms per square meter. This was a 78% decrease in density over the spring, 2004 sample. The James Canyon Creek fall, 2007 total densities fell closer to densities recorded in the fall of 2000, a low sample year. The decrease in density halted the trend of increasing density that occurred from the fall of 2001 until the spring of 2004.

Table 3. Total invertebrate densities per square meter for Burnout and James Canyon Creeks

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2007	Spring 2008
Burnout Creek	12590	35236	19995	38167	-	25178	55995	22513 **Error! Reference source not found.**	13281	26290
James Canyon Creek	34732	31344	11716	30309	40161	51488	109060	83719	33431	18079

Taxa Specific Densities

In Burnout Creek, fall 2007 (Table 4), the dominant species were: Diptera: Chironomidae (6,474/m^2), Ephemeroptera: *Paraleptophelbia* (1,706/m^2), and Annelida: Oligochaeta (1646/m^2).These made up 47%, 12% and 12% of the total density, respectively. The following taxa occurred in densities greater than 500 per square meter: Chironomidae (larvae) (Diptera), *Parlaleptophlebia* (Ephemeroptera), Oligochaeta (Annelida), *Heterlimnius* (larvae)

(Coeleoptera), and *Cinygmula* (Ephemeroptera).

In spring, 2008 the dominant species for Burnout Creek were (Table 4): Diptera: Chironomidae (15,332/m^2), Ephemeroptera: *Cingymula* (1444/m^2), and Annelida: Oligochaeta (970/m^2). These made up, 58%, 5%, and 4% of the total density, respectively. Within Burnout Creek the

Table 4. Summary of invertebrate densities by taxa for Burnout Creek Fall 2007 and Spring 2008

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Spring 2003	Fall 2003	Sprin g 2004	Fall 2007	Spring 2008
Ephemeroptera: *Baetis*	404	949	848	545	879	11403	3899	364	71
Ephemeroptera: *Cinygmula*	566	10	1050	636	525	4909	1263	869	1444
Ephemeroptera: *Drunella doddsi*			10			778		10	141
Ephemeroptera: *Drunella grandis*		20	20	10	40	61			646
Ephemeroptera: *Epeorus iron*				71	10		121		
Ephemeroptera: *Ephemerella*	182	20		71		91			
Ephemeroptera: early instar*			101			6222	929	20	3060
Ephemeroptera: *Heptagenia*	91			10					
Ephemeroptera: *Paraleptophlebia*	1161	40	525	10				1707	20
Ephemeroptera: *Rhithrogena*	10			10					
Ephemeroptera: *Serratella*							222		
Plecoptera: early instar*	50	20		10		20	626	162	
Plecoptera: *Diura knowltoni*	20								61
Plecoptera: *Hesperoperla pacifica*						10			
Plecoptera: *Isoperla*	71	10	10	10	20				
Plecoptera: *Malenka californica*	141								
Plecoptera: *Megarcys signata*			10						
Plecoptera: *Paraperla*									20
Plecoptera: *Skwalla parallela*		10		10		30			
Plecoptera: *Sweltza*	50		20			10			
Plecoptera: *Zapada*	10	10				40			30
Trichoptera: pupae					10		20		10
Trichoptera: *Amiocentrus*		10							
Trichoptera: *Brachycentrus echo*		10	30	10	10	1020			
Trichoptera: *Dicosmoecus*		10	131				10		10
Trichoptera: *Ecclisocosmoecus*	20								
Trichoptera: *Hydropsyche*					10	20			
Trichoptera: *Lepidostoma*	10	71		30			30		
Trichoptera: *Limnephilus*					10				
Trichoptera: *Micrasema*	10	131	141	242				40	
Trichoptera: *Moselyana*	20								
Trichoptera: *Neothremma alicia*	252	81	101	51	152	333	40		
Trichoptera: *Oligophlebodes*	40	202	515	30					
Trichoptera: *Platycentropus*		10							
Trichoptera: *Rhyacophila* (larvae)	121	101	121	202	576	707	111	51	172
Trichoptera: *Rhyacophila* (pupae)									
Coeleoptera: *Dryopidae*: (adult)								10	
Coeleoptera: Dyticidae (adult)									40
Coeleoptera: Dyticidae (larvae)								10	
Coleoptera: *Heterlimnius* (larvae)	353	2828	2505	455	10	20	525	949	869
Coleoptera: *Heterlimnius* (adult)	40	51	152	71			121	20	
Coleoptera: Hydrophilidae		10							
Coleoptera: *Optioservus* (larvae)	71			1262	1111	5838	859		10
Coleoptera: *Optioservus* (adult)				161	40	677	30		10
Coleoptera: Staphylinidae									40

Diptera: pupae*						30			
Diptera: *Agabus*					10				
Diptera: *Antocha* (larvae)	40	152		50					
Diptera: *Antocha* (pupae)		20							
Diptera: *Caloparyphus*		20	40				20	40	10
Diptera: Ceratopogonidae		20	20		30	2535		394	40
Diptera: *Chelifera*		121			10				
Diptera: Chironomidae (larvae)	3919	21927	2636	29685	13080	4192	3343	6474	1533 2
Diptera: Chironomidae (pupae)		485		1010	51	505	20		828
Diptera: *Dicranota*	20	10	10	10		20			30
Diptera: *Dixa*									152
Diptera: *Euparyphus*	20		10			61		20	
Diptera: *Neoplasta*									30
Diptera: *Pericoma*	111		10						
Diptera: *Ptychoptera*	81								
Diptera: *Rhabdomastix*									10
Diptera: *Simulium* (larvae)	121	30	323	81	212	2192	323		91
Diptera: *Simulium* (pupae)		30		10				20	
Diptera: *Tipula*	10	30	40	10	40	182	30		
Crustacea: *Asellus*	10								
Crustacea: Cladocera		495		545			313		
Crustacea: Copepoda				10	303	1525	303	30	333
Crustacea: Ostracoda	4202	5181	5656	1576	6454	10878	5787	10	313
Arachnida: Hydracarina	20	202		10	313	626	323	323	303
Mollusca: *Sphaerium*	40	364	253	364	929	1030	40	71	333
Mollusca: Physidae								30	
Annelida: Oligochaeta	303	899	3596	636	343	30	2747	1646	970
Tricladida: Planaridae		626	1111	263			424	40	51
Collembola		20					20	10	788
Nematoda							10	40	
Number of taxa*	33	34	27	30	23	26	22	22	28
Totals	12590	35236	19995	38167	25178	55995	22513	13281	26290

following taxa occurred in densities greater than 500 per square meter: *Cinygmula, Drunella grandis* (Ephemeroptera), early instar Ephemeroptera, *Heterlimnius* (Coleoptera), Chironomidae (Diptera), Collembola, and Oligochaeta (Annelida).

In the fall, 2007 James Canyon Creek sample series the dominant species were: Diptera: Chironomidae (larva) (12443/m^2), early instar Ephemeroptera (4676/m^2), and Crustacea: Copepoda (2141/m^2). These made up 37%, 14%, and 6% of the total density, respectively. Within James Canyon Creek the following taxa occurred in densities greater than 500 per square meter: Ephemeroptera: early instar Ephemeroptra, *Baetis*, *Cinygumla;* Plecoptera: early instar Plecoptera: *Zapada;* Trichoptera: Early instar Trichoptera; Coeleoptera: *Heterlimnius* (larvae); Diptera: Chironomidae (larvae and pupae), *Simulium*; Crustacea: Copepoda; Arachnid: *Hyracarnia;* Annelida: Oligochaeta; and Planaria

In the spring 2008 James Canyon Creek sample series dominant species were (Table 5) Chironomidae (larva) (14039/m^2), *Baetis* (555.5/m2) and Chironomidae (pupae) (404/m^2). These made up 77%, 3%, and 2% of the total density respectively. Within James Canyon Creek the following taxa occurred in densities greater than 500 per square meter: *Baetis*, Chironomidae early instar Ephemeroptera

Table 5. Summary of invertebrate densities by taxa for James Canyon Creek Fall 2007and Spring 2008

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Fall 2004	Fall 2007	Spring 2008
Ephemeroptera: *Baetis*	2848	1030	2444	404	6757	2283	18241	3010	1626	556
Ephemeroptera: *Cinygmula*	313	384	404	485		697	5040	535	1525	253
Ephemeroptera: *Drunella doddsi*			30				40		10	
Ephemeroptera: *Drunella grandis*		1566		1485		949	20			303
Ephemeroptera: *Epeorus iron*				10	283					141
Ephemeroptera: *Ephemerella*	980	20	10	91	2434		10			
Ephemeroptera: early instar	30		495			1010	2949	202	4676	687
Ephemeroptera: *Heptagenia*	30							1101		
Ephemeroptera: *Paraleptophlebia*	40		81	20	91				101	
Ephemeroptera: *Rhithrogena*		51								
Plecoptera: early instar	646	879	30	293	152	20	1626	768	960	10
Plecoptera: *Alloperla*						10				
Plecoptera: *Diura knowltoni*										
Plecoptera: *Hesperoperla pacifica*							61		10	
Plecoptera: *Isoperla*	71		51	10	212		10	20		
Plecoptera: *Malenka californica*	10		142		121					
Plecoptera: *Megarcys signata*			10							
Plecoptera: *Parleuctra*								111		
Plecoptera: *Paraperla*		10						10	71	40
Plecoptera: *Skwalla parallela*		414		61			111			
Plecoptera: *Sweltza*		10	30							
Plecoptera: *Zapada*	242	111	182	111	758		2010		2111	40
Trichoptera: early instar									667	
Trichoptera: *Allomyia*	131									
Trichoptera: *Amiocentrus*										
Trichoptera: *Arctopsyche grandis*	51		10		20					

Trichoptera: *Brachycentrus echo*		172		10						
Trichoptera: *Dicosmoecus*	10			30	10		182	10		10
Trichoptera: *Ecclisocosmoecus*										
Trichoptera: *Hydropsyche*		10			10		20			
Trichoptera: *Lepidostoma*		30	10		172			51		
Trichoptera: *Micrasema*	81		30							
Trichoptera: *Moselyana*										
Trichoptera: *Neothremma alicia*	3000	1384	758	727	2475	1848	869	1121	81	91
Trichoptera: *Oligophlebodes*		364	153	20				1273	10	
Trichoptera: *Platycentropus*										
Trichoptera: *(Pupa)*								40		
Trichoptera: *Rhyacophila* (al((s(larvae)	394	798	293	576	556	1040	515	980	172	71
Trichoptera: *Rhyacophila* (pupae)		30		30						
Coleoptera: *Curculionidae*								10		
Coleoptera: *Heterlimnius* (larvae)	30	192	51						657	61
Coleoptera: *Heterlimnius* (adult)		20		40						
Coleoptera: *Optioservus* (larvae)	10			1263	283	384	81	30		
Coleoptera: *Optioservus* (adult)				162	51		20	10		
Coleoptera: Staphylinidae		10	10			505				
Diptera: *Antocha* (larvae)	10			10	51					
Diptera: *Antocha* (pupae)										
Diptera: *Atherix*	10									
Diptera: *Atrichopogon*						10				
Diptera: *Caloparyphus*		51	20					30	20	10
Diptera: Ceratopogonidae	40	61		10		586	747	606	20	
Diptera: *Chelifera*	51	81		40		91	1030			
Diptera: Chironomidae (larvae)	23533	20614	4464	21947	19917	23351	62963	59751	12443	14039
Diptera: Chironomidae (pupae)	20	455	10	323	20	212	2424	141	535	404
Diptera: Chrysogaster						20				
Diptera: *Clinocera*										20
Diptera: *Dicranota*	20						51		71	
Diptera: *Dixa*		10				81		101		61
Diptera: *Euparyphus*	10		50		71		141		10	
Diptera: *Hemerodromia*		10		10				10		

Diptera: *Hemerodromia* pupae								20		
Diptera: *Limnophila*		20							20	
Diptera: *Neoplasta*									81	10
Diptera: *Pericoma*	30					1091				
Diptera: Phoridae			10							
Diptera: *Ptychoptera*			10					10		
Diptera: *Simulium* (larvae)	91	10	111		939	40	81	20	1071	51
Diptera: *Simulium* (pupae)										
Diptera: *Tipula*		10			61	81	455	30	71	20
Diptera: *Trichoclinocera*		10								
Diptera: *Wiedemannia*	81	91	20							
Crustacea: *Asellus*										
Crustacea: Cladocera		51		343		848				
Crustacea: Copepoda	10					596	980	909	2141	
Crustacea: Ostracoda									434	303
Crustacea: Ostracoda	1778	859	323	162	1202	10837	6363	7040	434	303
Arachnida: Hydracarina	10	101	20	81	20	1343	960	929	970	303
Mollusca: *Sphaerium*	20	354	71	141		3535	1040	364		303
Mollusca: *Gyraulus*				0			10	10		
Annelida: Hirudinea				0	10					
Annelida: Oligochaeta	101	192	40	394	71	20	10	2444	1313	71
Tricladida: Planaridae		828	1343	1020	3414			1990	1222	212
Collembola		51						20	323	10
Nematoda								10		
Number of taxa*	31	35	30	27	24	23	27	29	26	23
Totals	34732	31344	11716	30309	40161	51488	109060	83719	33431	18080

Biomass

The Burnout Canyon Creek fall, 2007 sampling site had a large decrease in biomass compared to previous biomass values, falling to 12.04g/m^2, a 76% decrease in biomass from the fall 2003 and the lowest biomass recorded for Burnout. The spring, 2008 samples were slightly higher in biomass than previous spring samples. The 2008 Burnout Creek biomass was a 2% increase from the spring, 2004 sample (Table 6). This biomass estimate still falls below the overall site average of 50.62 grams per square meter.

James Canyon Creek, fall 2007 samples recorded a decrease in biomass (Table 7). The fall biomass was similar to the biomass recorded in James Creek in fall of 2002. This drop is a reversal in the trend of increasing biomass that peaked fall of 2003. The biomass for spring, 2008 was 21.84 grams per square meter, a decrease of 55 % from the spring, 2004 biomass estimate. James Creek biomass values have decreased two consecutive spring samplings; returning to biomass values similar to spring 2001values. Both fall and spring samples were below the overall site average of 59.16 grams per square meter.

Table 6. Biomass in grams for Burnout Creek, 2000-2008

Burnout Creek									
Sample	**F2000**	**S2001**	**F2001**	**S2002**	**S2003**	**F2003**	**S2004**	**F2007**	**S2008**
1	**n/a**	2.02g	1.09g	1.04g	1.26g	3.30g	0.69g	0.27g	0.80g
2	**n/a**	0.67g	4.47g	0.94g	1.29g	2.90g	3.31g	0.37g	1.12g
3	**n/a**	0.48g	0.78g	1.93g	0.82g	2.54g	0.54g	0.55g	2.73
Total		3.17g	6.34g	3.91g	3.37g	8.74g	4.54g	1.19g	4.65g
per m^2	**g/m^2**	32.02g/ m2	64.03 g/m^2	39.49 g/m^2	34.04 g/m^2	88.27 g/m^2	45.87 g/m^2	12.04 g/m^2	46.97 g/m^2

Community Tolerance Quotient and Biotic Condition Indices

The community tolerance quotient (CTQa) was generated using the values for individual invertebrate taxa (see Appendix C) assigned in Winget and Mangum (1979). Under this measure lower values represent higher habitat qualities. Generally CTQa values less than 65 represent high quality waters, while those between 65 and 80 represent situations with moderate to high quality water (Winget and Mangum 1979). The CTQa values greater than 80 represent low water quality or stressed systems.

Table 7. Biomass in grams for James Canyon Creek, 2000-2008

	James Canyon Creek									
Sample	**F2000**	**S2001**	**F2001**	**S2002**	**F2002**	**S2003**	**F2003**	**S2004**	**F2007**	**S2008**
1	**n/a**	1.16g	0.86g	1.27g	1.03g	1.70g	4.90g	0.47g	1.97g	0.91g
2	**n/a**	0.72g	0.63g	2.89g	2.87g	**3.21g**	4.99g	**1.53g**	**2.29g**	**0.72g**
3	**n/a**	0.62g	0.84g	1.50g	0.55g	2.28g	5.41g	1.33g	0.24g	0.53g
Total		2.50g	2.33g	5.66g	4.45g	7.19g	15.30g	**3.33g**	**4.50g**	**2.16g**
per m^2	**g/m^2**	25.25 g/m^2	25.53 g/m^2	57.17 g/m^2	44.95 g/m^2	72.62 g/m^2	154.53 g/m^2	34.07 g/m^2	45.45 g/m^2	21.84 g/m^2

The CTQa value for fall 2007 Burnout Creek was 84.3, twenty points higher than the fall, 2003 sample. The CTQa value for Burnout Creek in the spring of 2008 was 77.1, less than a point greater than the spring, 2004 sample (Table 8). The average CTQa for Burnout was 66.3, which puts the current fall and spring CTQa value 21.2 and 11 points above the average, respectively. The fall 2007 CTQa for Burnout Creek indicates low water quality or a stressed system. The spring, 2008 value classifies Burnout Creek as having moderate water quality.

The CTQa values for James Canyon Creek, fall, 2007, and spring, 2008, both decreased from the previous sample group. The fall, 2007, CTQa value was 59.9, decreasing from fall, 2003 by 5.3 points. Spring of 2008 James Creek CTQa value was 63.1 which is 11.7 points lower than the spring, 2004 sample. The average CTQa value for James Creek was 66.2. The current spring and fall sample site recorded a decrease of 6.3 and 3.1 respectively from the previous average overall CTQa. This value classifies James Canyon Creek as having moderate water quality.

The BCI allows a comparison of a stream to a physical parameter-based estimate of water quality, the CTQp. The Huntington drainage has a CTQp rated at an 80, the BCI = 100 X CTQp/CTQa = 100 X 80/CTQa. Since both streams were rated with the same CTQp value, the BCI will give results parallel with the CTQa. The BCI values for Burnout fall 2007 and spring 2008 were 94.9 and 103.8 respectively. These most recent BCI values for the Burnout Creek sample site are lower than the site average of 122.3 (Table 8). The BCI values for James Canyon fall 2007 and spring 2008 were 133.6 and 126.8 respectively, which is above the site average of 117.7.

According to the CTQa and BCI indices, Burnout Creek continues a trend in towards lower stream quality. James Canyon Creek continued towards improved stream quality, exhibiting a CTQa of 59.9 in the fall, then raising to 63.1 CTQa in the spring; the lowest spring CTQa for that sample site. In general the CTQa has a seasonal periodicity, generally being higher in the spring (ie. lower water quality), and lower in the fall. However, the Burnout Creek fall 2007 CTQa is higher than the spring 2008 sample. It appears James Creek is improving its quality based on BCI and CTQa.

Table 8. CTQa and BCI values for Burnout and James Canyon Creeks

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2007	Spring 2008
	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI	CTQa /BCI
Burnout Creek	58.3 /137.2	60.8 /131.6	60.0 /133.3	64.1 /124.8	----	80.1 /99.9	64.4 / 124.3	76.3 /104.8	84.3 /94.9	77.1 /103.8
James Canyon Creek	65.6 /121.9	72.0 /111.1	68.7 /116.4	66.1 /121.0	59.0 /135.9	76.0 /105.3	65.2 / 122.7	74.8 /107.0	59.9 /133.6	63.1 /126.8

Diversity Indices

Diversity indices combine both number of taxa and relative densities into a single measurement. High diversity index values indicate more taxa and a more even number of individuals per taxon. Low diversity values generally reflect a depauperate fauna in both species and somewhat in numbers, although very high densities in just a few taxa will also lower diversity scores.

Burnout Creek diversity index values were 1.806 for fall 2007 and 1.729 for spring 2008. Both spring and fall diversity index values were lower than the Burnout Creek site average of 1.821. James Canyon Creek, in fall 2007 and spring 2008 diversity index values were 2.17 and 1.068 respectively. The fall sample site was greater than the site average of 1.556, but the spring 2008 value is below this site's average. Both Burnout and James Canyon creeks have diversity levels that are reasonably good (see reference levels for Eccles Creek in Shiozawa 2002) although not nearly as high as one would expect for a generally unimpacted system. Part of this may be an artifact associated with the relatively small sample size of three replicates per stream prescribed for these two locations.

Of the two streams, Burnout Creek has tended to have a higher diversity, especially in the fall. However fall, 2007 Burnout was lower than James Creek. This signal is similar to that seen in the CTQa and BCI indices (table 8) for Burnout Creek. Yet the seasonal signal is not apparent in the James Canyon Creek diversity indices. However, in contrast with the CTQa trends, where Burnout Creek appeared to converge towards the conditions existing in James Canyon Creek, the diversity indices indicate that Burnout Creek has maintained a more diverse community than James Canyon. In addition, James Canyon Creek is showing a decline in diversity to levels similar to those in the springs of 2001 and 2002.

Table 9. Diversity indices, based on natural logs, for Burnout and James Canyon Creeks

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Spring 2004	Fall 2007	Spring 2008
Burnout Creek	2.032	1.459	2.202	1.111	--	1.550	2.310	2.080	1.806	1.729
James Canyon Creek	1.246	1.519	2.112	1.279	1.747	1.854	1.451	1.241	2.17	1.068

Cluster Analysis

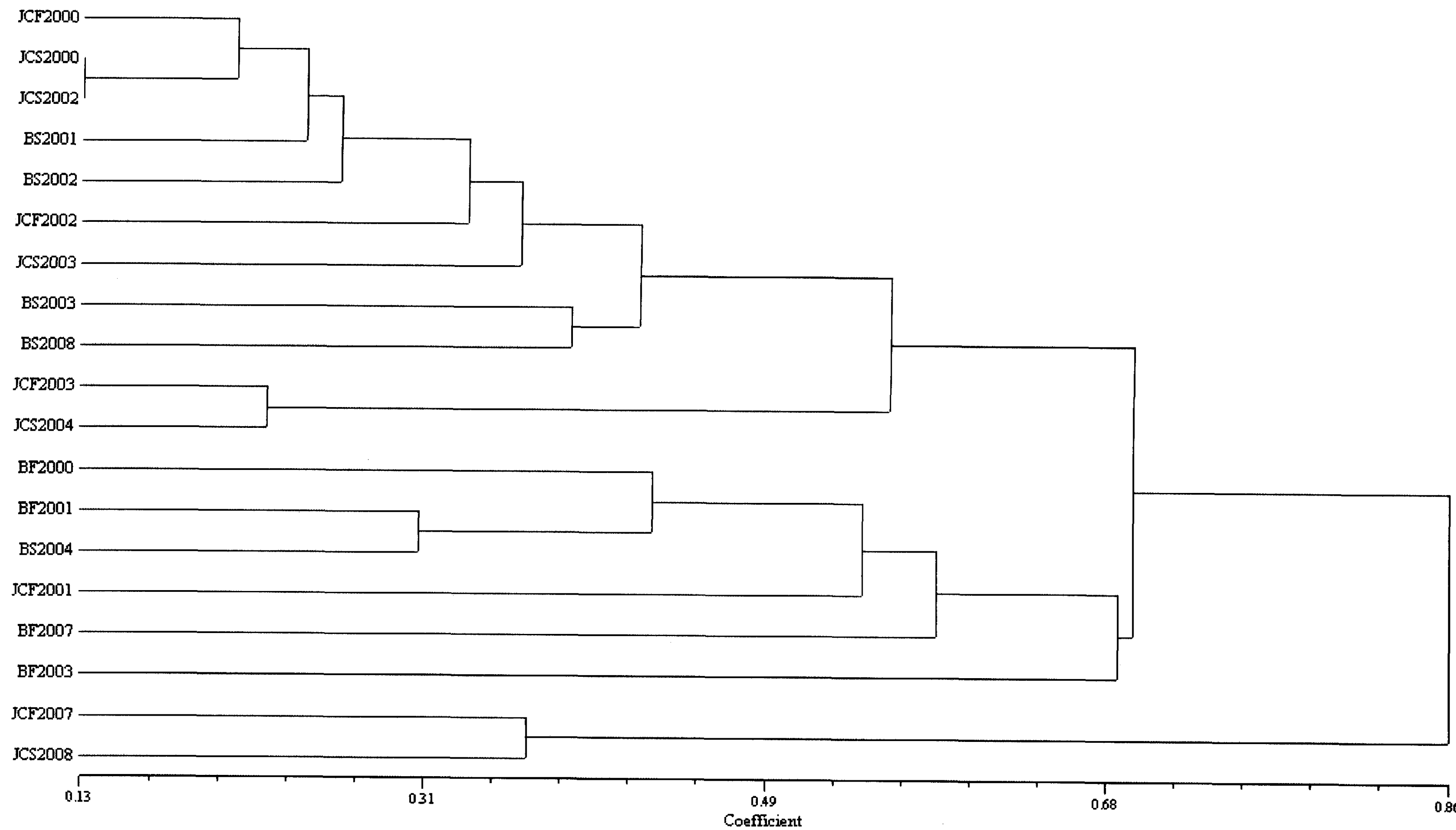
Cluster analysis (Figure 1) resulted in two main clusters separated at a dissimilarity value of approximately 0.86. The top cluster (cluster 1) contains two subclusters. One is predominantly made up of spring samples and the other of fall samples of both Burnout Creek and James Canyon Creek. The Burnout spring, 2008, sample, occurred in the spring subcluster, grouping with other samples at approximately 0.39 dissimilarity value. The fall, 2007, Burnout sample was in the fall subcluster, grouping with other fall samples at approximately 0.69 dissimilarity value.

However the James Canyon Creek fall, 2007 and spring, 2008 samples fell into the second cluster with a dissimilarity value of approximately 0.86. These two samples comprised the only members of this cluster and are the most dissimilar samples that have been taken to date. This high dissimilarity indicates that even if fish predation was a major player in the community structure, the shift was not back to the conditions prior to the exclusion of fish. Instead the community composition has gone on towards a different trajectory.

Conclusions

Both Burnout Creek and James Canyon Creek for this sampling period had fewer taxa than during the first few years of the study. Total invertebrate densities in both streams declined to below average for the 2007 and 2008 sampling periods, but were still within the expected range. However, Burnout Creek spring of 2008 densities were higher than the spring 2004 sampling period. James Canyon Creek had higher than average densities in 2004, but the fall 2007 and spring 2008 sampling period greatly declined. In spring, 2008 Burnout Creek had an increase in density for seven of its 28 taxonomic categories, while in James Canyon Creek chironomids, comprising nearly 77% of the sample, continued to be the dominant taxon. *Baetis* densities remained in the normal range but *Neothremma* declined to low levels. Burnout Creek saw a dramatic decrease in the number of *Baetis* and ostracoda, but the chironomids increased significantly.

Figure 1. UPGMA Cluster dendrogram of relationships among communities from Burnout and James Canyon Creeks



Biomass in Burnout Creek was low in the fall of 2007, but was normal in the Spring of 2008. In contrast James Canyon Creek biomass was normal in the fall of 2007 but it was low in the fall of 2008. Burnout Creek had greater CTQa values in the fall of 2007 than in the spring, 2008 sample period, and showed lower CTQa values than the previous spring and fall samples (fall, 2007; spring, 2004), indicating a slight decrease in habitat quality. A seasonal signal was not apparent in the CTQa values from Burnout Creek, which did not follow the previous trend of being high in the spring and lower in the fall samples. However, James Canyon Creek did not follow this trend and had lower CTQa values than the previous spring and fall samples, indicating that, for James Canyon, there was a slight increase in habitat quality.

Cluster analysis identifies a seasonal signal for Burnout Creek. The Burnout Creek spring samples have a low diversity and are found in the fall subcluster. The fall samples for Burnout Creek are found in the lower section of cluster one (spring subcluster) and have a higher diversity value. The Fall 2007 and Spring 2008 James Canyon samples are in a separate cluster relative to the two subclusters noted above. The cause of this is unclear, but the fall cluster had high diversity while the Spring 2008 sample diversity was very low, indicating that membership in this subcluster is not directly driven by diversity.

It appears that the trends seen in the two streams in fall 2007 and spring 2008 are driven by different factors. Burnout Creek in the fall of 2007 had low taxa, low total densities (associated with low densities of *Baetis* and ostracods), diversity, and very low biomass. Causes of this change are not known although the fall 2007 fish monitoring found high densities of small tiger trout stocked in the stream. No tiger trout were collected above the second waterfall on this stream, but that does not preclude the stocking of fish above the falls. Such stocking would have impacted the invertebrate community.

High runoff resulted in over-bankfull discharge in both streams beyond June of 2008, delaying the spring sampling until well into the summer. The associated scouring could also be a significant factor in the reduced number of invertebrates in James Canyon Creek, although the flooding was also monitored in Burnout Creek, which did not show the same decrease in densities.

James Canyon Creek enters Electric Lake through a culvert. After the level of Electric Lake fell below the outflow end of the culvert in about 2001, a significant portion of the stream discharge exiting the culvert sank into the exposed sand bed of the lake. This formed a barrier to fish spawning access to James Canyon Creek and resulted in the loss of the trout population in the stream (Shiozawa 2006). By 2007 several wet years had increased the level of Electric Lake well above the stream outflow pipe. Spawning cutthroat trout again gained access to James Canyon Creek and in 2007 successful reproduction of cutthroat trout was noted in the stream (Shiozawa 2008). The reinvasion and successful reproduction of trout in the stream may have been a significant driver in the change in taxa and densities recorded in the James Canyon Creek benthic community.

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Appendix A: Sample Data for Burnout Creek Spring 2008

Burnout Creek - Spring 2008		Site 1	Site 2	Site 3	Mean	Density
Ephemeroptera	*Baetis sp.*	3	2	2	2.33	70.7
	Cinygmula	63	10	70	47.67	1444.3
	Drunella doddsi	3	5	6	4.67	141.4
	Drunella grandis	6	22	36	21.33	646.4
	Early instar Ephemeroptera	4	35	264	101.00	3060.3
	Paraleptophlebia	0	2	0	0.67	20.2
Plecoptera	*Early instar plecoptera*	0	1	5	2.00	60.6
	Paraperla frontalis	1	1	0	0.67	20.2
	Zapada	2	0	1	1.00	30.3
Trichoptera	*Tricoptera pupae*	1	0	0	0.33	10.1
	Dicosmoecus	0	0	1	0.33	10.1
	Rhyacophila (larvae)	2	6	9	5.67	171.7
Coeleoptera	*Dytiscidae*	0	2	2	1.33	40.4
	Heterlimnius (larvae)	37	16	33	28.67	868.6
	Optioservus (larvae)	0	0	1	0.33	10.1
	Optioservus (adult)	0	0	1	0.33	10.1
	Staphylinidae	2	1	1	1.33	40.4
Diptera	*Caloparyphus*	0	1	0	0.33	10.1
	Ceratopogonidae	0	2	2	1.33	40.4
	Chironomidae *(larva)*	294	649	575	506.00	15331.8
	Chironomidae *(pupae)*	8	34	40	27.33	828.2
	Dicranota (Tipulidae)	0	3	0	1.00	30.3
	Dixa (Dixidae)	1	4	10	5.00	151.5
	Rhabdomastix	0	1	0	0.33	10.1
	Neoplasta	0	1	2	1.00	30.3
	Simulium (Simulidae)	1	1	7	3.00	90.9
Crustacea	*Ostracoda*	0	0	31	10.33	313.1
	Copepoda	1	0	32	11.00	333.3
Arachnid	*Hydracarnia*	0	30	0	10.00	303
Mollusca	*Sphaerium sp.*	2	30	1	11.00	333.3
Annelida	*Oligochaeta*	68	15	13	32.00	969.6
Misc.	Collembola	33	2	43	26.00	787.8
	Hemiptera	0	0	2	0.67	20.2
	Planaria	0	0	5	1.67	50.5
	Totals	*532*	*876*	*1195*	867.67	26290.3

Burnout Creek - Fall 2007		Site 1	Site 2	Site 3	Mean	Density
Ephemeroptera	*Baetis sp.*	2	1	33	12.000	363.6
	Cinygmula sp.	44	37	5	28.667	868.6
	Drunella doddsi	1	0	0	0.333	10.1
	Early instar Ephemeoptera	1	0	1	0.667	20.2
	Paraleptophlebia sp.	38	56	75	56.333	1706.9
Plecoptera	Early instar Plecoptera	5	6	5	5.333	161.6
Trichoptera	*Micrasema bactro*	0	0	4	1.333	40.4
	Rhyacophila (larvae)	2	1	2	1.667	50.5
Coeleoptera	*Heterlimnius* (larvae)	6	28	60	31.333	949.4
	Heterlimnius (adult)	1	1	0	0.667	20.2
	Dryopidae (adult)	0	0	1	0.333	10.1
	Dyticidae(larvae)	0	0	1	0.333	10.1
Diptera	*Caloparyphus* (Stratiomyideae)	1	0	3	1.333	40.4
	Ceratopogonidae	33	3	3	13.000	393.9
	Chironomidae (larvae)	353	161	127	213.667	6474.1
	Simulium (Simulidae)	0	0	2	0.667	20.2
	Euparyphus	1	1	0	0.667	20.2
Crustacea	Copepoda	0	2	1	1.000	30.3
	Ostracoda	0	1	0	0.333	10.1
Arachnida	Hydracarina	0	1	31	10.667	323.2
Mollusca	*Sphaerium sp.*	0	1	6	2.333	70.7
	Physidae	3	0	0	1.000	30.3
Annelida	Oligochaeta	64	37	62	54.333	1646.3
Misc.	Collembola	0	0	1	0.333	10.1
	Planaridae	3	0	1	1.333	40.4
	Nematoda	0	4	0	1.333	40.4
	Hemiptera	0	0	1	0.333	10.1
	Totals	*555*	*337*	*424*	441.333	13281.5

Appendix B. Sample data for James Canyon Creek Fall 2008

James Canyon Creek- Spring 2008		Site 1	Site 2	Site 3	Mean	Density
Ephemeroptera	*Baetis sp.*	31	13	11	18.33	555.5
	Cinygmula	17	1	7	8.33	252.5
	Drunella grandis	12	16	2	10.00	303
	Early instar Ephemeroptera	31	32	5	22.67	686.8
	Epeorus iron	7	7	0	4.67	141.4
Plecoptera	*Early instar plecoptera*	0	1	0	0.33	10.1
	Paraperla frontalis	1	1	2	1.33	40.4
	Zapada	2	1	1	1.33	40.4
Trichoptera	*Dicosmoecus*	0	1	0	0.33	10.1
	Neothremma alicia	5	3	1	3.00	90.9
	Rhyacophila (larvae)	3	3	1	2.33	70.7
Coeleoptera	*Heterlimnius* (larvae)	0	2	4	2.00	60.6
Diptera	*Caloparyphus sp*	0	1	0	0.33	10.1
	Chironomidae *(larva)*	967	146	277	463.33	14039
	Chironomidae *(pupae)*	6	30	4	13.33	404
	Clinocera	2	0	0	0.67	20.2
	Dixa (Dixidae)	6	0	0	2.00	60.6
	Neoplasta	0	0	1	0.33	10.1
	Simulium (Simulidae)	4	1	0	1.67	50.5
	Tipula (Tipulidae)	0	0	2	0.67	20.2
Crustacea	*Ostracoda*	0	0	30	10.00	303
Arachnid	*Hydracarnia*	30	0	0	10.00	303
Mollusca	*Sphaerium sp.*	30	0	0	10.00	303
Annelida	*Oligochaeta*	2	3	2	2.33	70.7
Misc.	Collembola	1	0	0	0.33	10.1
	Planaria	3	11	7	7.00	212.1
	Totals	*1160*	*273*	*357*	596.67	18079

James Canyon Creek- Fall 2007		Site 1	Site 2	Site 3	Mean	Density
Ephemeroptera	*Baetis sp.*	108	53	0	53.67	1626.1
	Cinygmula	92	21	38	50.33	1525.1
	Drunella doddsi	1	0	0	0.33	10.1
	Early instar Ephemeroptera	210	46	207	154.33	4676.3
	Paraleptophlebia	8	1	1	3.33	101
Plecoptera	*Early instar plecoptera*	86	9	0	31.67	959.5
	Hesperoperla pacifica	1	0	0	0.33	10.1
	Paraperla frontalis	1	3	3	2.33	70.7
	Zapada	185	16	8	69.67	2110.9
Trichoptera	Early instar Trichoptera	64	2	0	22.00	666.6
	Oligophlebodes	0	1	0	0.33	10.1
	Neothremma alicia	8	0	0	2.67	80.8
	Rhyacophila (larvae)	2	6	9	5.67	171.7
Coeleoptera	*Heterlimnius* (larvae)	44	14	7	21.67	656.5
Diptera	*Caloparyphus (Stratiomyidae)*	0	1	1	0.67	20.2
	Ceratopogonidae	0	2	0	0.67	20.2
	Chironomidae *(larva)*	810	279	143	410.67	12443.2
	Chironomidae *(pupae)*	7	14	32	17.67	535.3
	Dicranota (Tipulidae)	2	2	3	2.33	70.7
	Euparyphus (Stratiomyidae)	0	1	0	0.33	10.1
	Limnophila	0	2	0	0.67	20.2
	Neoplasta	1	5	2	2.67	80.8
	Simulium (Simulidae)	81	19	6	35.33	1070.6
	Tipula (Tipulidae)	2	5	0	2.33	70.7
Crustacea	*Ostracoda*	38	4	1	14.33	434.3
	Copepoda	211	1	0	70.67	2141.2
Arachnid	*Hydracarnia*	63	0	33	32.00	969.6
Annelida	*Oligochaeta*	109	2	19	43.33	1313
Misc.	Collembola	2	0	30	10.67	323.2
	Hemiptera	1	0	0	0.33	10.1
	Planaria	50	4	67	40.33	1222.1
	Totals	*2187*	*513*	*610*		33431

Appendix C. Tolerance quotients for Burnout and James Canyon Creeks

Burnout and James Canyon Creeks Spring 2004 Taxa	Burnout Creek Fall 2007	James Canyon Creek Fall 2007	Burnout Creek Spring 2008	James Canyon Creek Spring 2008	Ideal Stream
Ephemeroptera: Baetidae: *Baetis spp.*	72	72	72	72	72
Ephemeroptera: Ephemerellidae: *Drunella doddsi*	4	4	4		4
Ephemeroptera: Ephemerellidae: *Drunella grandis*			24	24	24
Ephemeroptera: Ephemerellidae: *Ephemerella*					48
Ephemeroptera: Ephemerellidae: *Serratella tibialis*		24			24
Ephemeroptera: Heptageniidae: *Cinygmula*	21	21	21	21	21
Ephemeroptera: Heptageniidae: *Epeorus iron*				21	21
Ephemeroptera: Heptageniidae: *Heptagenia*					48
Ephemeroptera: Heptageniidae: *Rhithrogena*					21
Ephemeroptera: Leptophlebiidae: *Paraleptophlebia*	24	24	24		24
Plecoptera: Chloroperlidae: *Alloperla*					24
Plecoptera: Chloroperlidae: *Paraperla frontalis*		24	24	24	24
Plecoptera: Chloroperlidae: *Sweltza*					24
Plecoptera: Leuctridae: *Paraleuctra*					18
Plecoptera: Nemouridae: *Malenka californica*					36
Plecoptera: Nemouridae: *Zapada*		16	16	16	16
Plecoptera: Perlidae: *Hesperoperla pacifica*		18			18
Plecoptera: Perlodidae: *Diura knowltoni*					24
Plecoptera: Perlodidae: *Isoperla*					48
Plecoptera: Perlodidae: *Megarcys signata*					24
Plecoptera: Perlodidae: *Skwalla parallela*					18
Trichoptera: Brachycentridae: *Amiocentrus*					24
Trichoptera: Brachycentridae: *Brachycentrus*					24
Trichoptera: Brachycentridae: *Micrasema*	24				24
Trichoptera: Hydropsychidae: *Arctopsyche grandis*					18
Trichoptera: Hydropsychidae: *Hydropsyche*					108
Trichoptera: Lepidostomatidae: *Lepidostoma*					18
Trichoptera: Limnephilidae: *Imania* (*Allomyia*)					48

Trichoptera: Limnephilidae: *Dicosmoecus*			24	24	24
Trichoptera: Limnephilidae: *Ecclisocosmoecus*					108
Trichoptera: Limnephilidae: *Limnephilus*					108
Trichoptera: Limnephilidae: *Moselyana*					108
Trichoptera: Limnephilidae: *Platycentropus*					108
Trichoptera: Rhyacophilidae: *Rhyacophila*	18		18	18	18
Trichoptera: Uenoidae: *Neothremma alicia*				8	8
Trichoptera: Uenoidae: *Oligophlebodes*					24
Coleoptera: Curculionidae					72
Coleoptera: Dryopidae	108		108		108
Coleoptera: Dytiscidae:	72		72		72
Coleoptera: Elmidae: *Heterlimnius*	108	108	108	108	108
Coleoptera: Elmidae: *Optioservus*			108		108
Coleoptera: Hydrophilidae					72
Coleoptera: Staphylinidae			108		108
Diptera: pupae					108
Diptera: Athericidae: *Atherix*					24
Diptera: Ceratopogonidae	108	108	108		108
Diptera: Ceratopogonidae: Atrichopogon					108
Diptera: Chironomidae	108	108	108	108	108
Diptera: Dixidae: *Dixa*			108	108	108
Diptera: Empididae: *Chelifera*					108
Diptera: Empididae: *Clinocera*				108	108
Diptera: Empididae: *Hemerodromia*					108
Diptera: Empididae: *Neoplasta*		108	108	108	108
Diptera: Empididae: *Trichoclinocera*					108
Diptera: Empididae: *Wiedemannia*					108
Diptera: Limoniidae: *Rhabdomastix*			108		108
Diptera: Muscidae: *Limnophora*					108
Diptera: Phoridae					108
Diptera: Psychodidae: *Pericoma*					36
Diptera: Ptychopteridae: *Ptychoptera*					108
Diptera: Simuliidae: *Simulium*	108	108	108		108

Diptera: Syrphidae: *Chrysogaster*					108
Diptera: Stratiomyidae: *Caloparyphus*	108	108	108	108	108
Diptera: Stratiomyidae: *Euparyphus*	108	108			108
Diptera: Tipulidae: *Antocha*					24
Diptera: Tipulidae: *Dicranota*		24	24		24
Diptera: Tipulidae: *Limnophila*		72			72
Diptera: Tipulidae: *Tipula*		36		36	36
Crustacea: Cladocera					108
Crustacea: Copepoda	108		108		108
Crustacea: Isopoda: *Asellus*					108
Crustacea: Ostracoda	108	108	108	108	108
Arachnida: Hydracarina	108	108	108	108	108
Mollusca: Planorbidae: *Gyraulus*					108
Mollusca: Physidae	108				108
Mollusca: Sphaeriidae: *Sphaerium*	108				108
Annelida: Hirudinea					108
Annelida: Oligochaeta	108	108	108	108	108
Tricladida: Planariidae	108	108	108	108	108
Collembola	108	108	108	108	108
Nematoda					108
Total	1855	1559	2159	1452	5671
Number of taxa	22	26	28	23	81
CTQa	84.3	59.9	77.1	63.1	70.0

AN ASSESSMENT OF THE MACROINVERTEBRATES OF WOODS CANYON CREEK AND WINTER QUARTERS CREEK CARBON COUNTY, UTAH

in

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Introduction

The coal underlying both Woods Canyon and Winter Quarters Canyon is scheduled to be mined. This report gives the results of the second year of monitoring of the benthos of the stream system. These data will establish baseline conditions against which any impacts due to the mining and subsequent subsidence can be compared.

Methods

Sample placement was determined by examination of the stream systems on USGS 7.5 minute quadrangles. Two to three reaches were examined on each stream, with each reach being defined by the inflow of a side stream and the general distance from the previous reach. The lowest reaches in the two streams were established on U. S. Forest Service land above the boundary with private grazing lands. The location of each reach is given in Table 1. Four riffles were sampled within each reach in the fall of 2002, but this was increased to 8 riffles in the spring of 2004. Two samples were taken at each riffle and were bulked together in the field.

Table 1. Sampling station locations

Canyon	Reach	GPS coordinates	Elevation
Woods	Upper	N 39° 44.340' W 111° 13.471' UTM4398045 12S0480808	2609 m (8560 ft)
Woods	Lower	N 39° 44.071' W 111° 12.592'	2552 m (8374 ft)
Winter Quarters	Upper	N 39° 42.763' W 111° 13.907'	2587 m (8488 ft)
Winter Quarters	Middle	N 39° 42.933' W 111° 13.378'	2571 m (8434 ft)
Winter Quarters	Lower	N 39° 43.126' W 111° 12.807'	2519 m (8265 ft)

Physical characteristics for each reach were recorded (Table 2, 3). These included pH, conductivity, in micro-Siemens/cm (uS/cm), alkalinity, and hardness. Alkalinity and hardness were measured with a Hach water chemistry kit. Slope was recorded with an inclinometer, across a 100 meter length of stream, beginning at the first (starting downstream) riffle. The stream channel within each reach was characterized by measuring the width, depth, and velocity of the stream every five meters, beginning with the first riffle. Three depth and velocity measures were taken at each five meter interval, these being at the center and approximately 10% of the width from either shore.

Quantitative invertebrate samples were taken with a modified box sampler (Shiozawa 1986) using a capture net with a net mesh of 253 microns. Samples were taken from each of the three reaches in Winter Quarters Canyon and the two reaches in Woods Canyon. Samples were concentrated in the field in sieves with 63 micron mesh, preserved with ethyl alcohol, and were returned to the laboratory for processing. In the laboratory the samples were sorted in an illuminated pan. Organisms were identified to the lowest taxonomic unit possible. Small specimens and those of questionable identity were further examined under magnification. Identification was based on the keys of Merritt and Cummins (1996) and Merritt, Cummins, and Berg (2008). The mean values for each taxon were used to determine the density of invertebrates per square meter. Standing crop was estimated from wet weights of total invertebrates collected at the station.

The USFS Biotic Condition Index (Winget and Mangum 1979) was calculated with the community tolerance quotient (CTQa). The predicted community tolerance quotient (CTQp), based on water chemistry data provided in Winget (1972) for the Huntington Creek drainage, is 80. Diversity was calculated for each reach using the Shannon-Weiner index (Pielou 1977). Diversity indices take the number of taxa and their individual densities into account, generating a single value for each station. The greater the number of species or taxa and generally the more even the distribution of densities between taxa, the higher the diversity index value.

Cluster analysis was run with NTSYS-pc (Rolf 2000), using the Bray-Curtis dissimilarity index with the UPGM clustering algorithm. Data from all reaches for the first two sampling periods (fall 2002 and spring 2003) and from both Woods Canyon Creek and Winter Quarters Canyon Creek were included in the cluster analysis.

Since these samples are to be used to establish pre-mining base-line information, the most important information for future assessment will be the actual densities and taxa lists. The CTQa, diversity indices, and cluster analysis will serve to help understand relative associations between the two streams, seasonality effects, and within stream trends. As with all field collected data, annual variations in weather patterns (e.g. drought) will need to be taken into account in interpreting the data.

Results and Discussion

Physical Characterization

The stream channel slopes also become shallower as the streams proceed down the canyons, a typical geomorphological profile for stream systems draining mountainous areas (Horton 1945). Channel depth and width increase downstream, as would be expected with the influx of additional water from the watershed and mean velocity also increased downstream, despite the decline in the stream channel slope. The increase in velocity is likely related to the increase in discharge in the lower reaches of the stream system, the greater mean depth, and the reduced turbulence associated with the increase in depth.

The chemical characteristics of the streams appear typical for high desert systems draining exposed sedimentary bedrock. As a general rule, alkalinity, hardness, and conductivity increased in the downstream reaches as the water in the channel accumulated salts from streams, springs, and seeps enters the main channel. All three are measures of ions in the water. Alkalinity is generally a measure of carbonate concentration, while hardness is a measure of divalent cations (mainly Ca and Mg). In these two streams the total hardness is almost always greater than alkalinity. The exception in the upper station in Winter Quarters Canyon in July 2008 is likely due to the high runoff during that spring and early summer. If the ions in the systems were purely due to carbonates of calcium and magnesium, we would expect alkalinity to equal hardness. However higher hardness readings for most sampling periods indicates that the remaining anions in the system are chlorides, sulfates, silicates, or nitrates (Boyd 1990). Given the origin of the bedrock it is likely that the major anions are sulfates and chlorides. It does appear that in the spring, the upper reach of Winter Quarters Canyon has a higher portion of its anions made up of these unmeasured species, even though the total ion loads are about a third of the fall concentration. This could be associated with a differential mobilization of anions during the higher discharge associate with the spring runoff. The anomalous 2008 sample suggests a decrease in divalent cations since the alkalinity stayed within the range of previous years. The hardness reading could be in error but the conductivity reading also decreased, which indicates decreased dissolved ions.

The pH shows a general trend of increasing downstream. The pH, while at the high end of the normal scale for natural waters (about 8.5; Hem 1971) may be partially confounded with time of day, since our standard sampling protocol starts with sample collection in the upstream reach first and then we progressively sample the downstream reaches. Such an approach could be biased by the amount of photosynthetic activity taking place in the stream channel. The upper reaches of these two stream systems often have greater amounts of sand while the lower reaches tend to be embedded and often somewhat cemented in by travertine, a calcium carbonate deposit. The photosynthetic activity of algae, as well as the physical loss of carbon dioxide from the stream water will cause the precipitation of travertine on the substratum (Hynes 1972). Algae utilizes bicarbonate for the carbon source in photosynthesis, and in the process increases the pH. This facilitates the precipitation of calcium carbonate. Photosynthesis takes place during the day, increasing as the light intensity increases. Thus in the afternoon, photosynthesis would be maximum and that is the same time that we tend to be sampling the downstream reaches of the two streams.

Biological Characterization

Number of Taxa

The Upper Woods Canyon sample site for fall 2007 recorded a decrease, but an increase in taxa numbers for the spring 2008. The September 2007 sample for Upper Woods had 37 different taxa. This was a 12% decrease from the previous fall sample. The July 2008 sample recorded 40 taxa, an 8% increase from the spring 2004 sample (Table 4). The Lower Woods Canyon sample site had 42 taxa in the fall of 2007, unchanged from the fall 2003 sample series, but the spring 2008 recorded an increase in number of taxa over the spring 2004 samples. The July 2008 sample recorded 41 taxa, an increase of 5% from the previous spring samples (Table 4).

The Upper Winter Quarters Canyon sample site for fall 2007 had 39 taxa, an 11% increase from

Table 2. Physical Characterization of Woods Canyon Creek

Date	Site	Alkalinity mg/L $CaCO_3$ equivalents	Hardness mg/L $CaCO_3$ equivalents	Conductivity (uS/cm)	slope	depth (cm)	width (m)	velocity (m/s)	pH
10/19/02	1 2	136.8 188.1	273.6 324.9	415 452	4.0° 3.5°	3.6 4.333	1.213 1.157	0.268 0.327	8.30 8.23
6/27/03	1 2	119.7 136.8	222.3 239.4	351 393	4.0° 3.5°	5.267 6.250	1.645 1.345	0.187 0.276	8.18 8.42
10/13/03	1 2	220 260	320 320	380 440	4.0° 3.5°	2.650 3.66	1.048 1.038	0.140 0.118	8.63 7.73
6/28/04	1 2	220 240	240 240	340 405	4.0° 3.5°	5.56 4.76	1.919 1.580	0.174 0.244	8.52 8.36
9/25/07	1 2	160 160	180 180	377 446	4.0° 3.5°	7.53 5.00	1.296 1.591	0.181 0.175	8.43 8.40
7/17/08	1 2	120 120	200 240	313 396	4.0° 3.5°	6.42 8.73	2.304 1.793	0.454 0.493	8.41 8.33

1 - Upper Site 2 - Lower Site

Table 3. Physical Characterization of Winter Quarters Creek

Date	Site	Alkalinity mg/L $CaCO_3$ equivalents	Hardness mg/L $CaCO_3$ equivalents	Conductivity (uS/cm)	slope	depth (cm)	width (m)	velocity (m/s)	pH
10/18/02	1 2 3	119.7 136.8 136.8	188.1 273.6 256.5	343 371 390	4.0° 3.0° 2.5°	5.8 6.367 6.983	1.028 1.252 2.129	0.199 0.240 0.222	8.26 8.34 8.32
6/20/03	1 2 3	51.3 85.5 119.7	136.8 153.9 205.2	239 275 352	4.0° 3.0° 2.5°	8.633 8.3 11.433	1.215 1.799 2.07	0.224 0.333 0.399	8.39 8.60 8.62
10/15/03	1 2 3	140 200 180	240 260 260	280 310 280	4.0° 3.0° 2.5°	4.817 6.433 5.266	0.978 1.945 1.680	0.210 0.275 0.240	8.57 8.55 8.58
6/30/04	1 2 3	160 180 180	160 200 240	260 294 353	4.0° 3.0° 2.5°	6.066 7.133 8.833	1.10 1.45 1.83	0.254 0.348 0.345	8.60 8.48 8.52
10/4/07	1 2 3	140 140 140	200 200 220	317 363 390	4.0° 3.0° 2.5°	5.917 7.233 9.600	1.059 1.853 2.183	0.168 0.242 0.2999	8.49 8.54 8.66
7/19/08	1 2 3	160 140 140	100 220 200	247 308 355	4.0° 3.0° 2.5°	8.700 10.47 13.867	1.398 2.19 2.631	0.4638 0.5086 0.6348	8.43 8.56 8.68

1 - Upper site 2 - Middle site 3 - Lower Site

the fall of 2003. The July 2008 sample recorded 34 taxa, a 19% decrease from the spring 2004 samples (Table 4). The October 2007 sample for Middle Winter Quarters recorded 39 different taxa, a 15% increase from the fall 2003 samples. The June 2004 sample recorded 33 taxa, a 27% decrease from the previous spring samples (Table 4). The Lower Winter Quarters Canyon sample sites for fall 2007 recorded 41 different taxa, a 11% increase from the fall 2003 sample. The 35 taxa in July 2008 was a 20% decrease from the previous spring 2004 samples (Table 4).

Table 4. Number of Taxa collected from Woods and Winter Quarter Canyons

	Shiozawa 2006	Shiozawa 2006	this report	this report
Sampling date	October 2003	June 2004	Sept/Oct 2007	July 2008
Upper Woods Canyon	42	37	37	40
Lower Woods Canyon	42	39	42	41
Upper Winter Quarters Canyon	35	42	39	34
Middle Winter Quarters Canyon	34	45	39	33
Lower Winter Quarters Canyon	37	44	41	35

Total Densities

Upper Woods Canyon recorded an increase in total density for both the fall 2007 sample and the spring 2008 sample. The September 2007 recorded 181,813 per square meter. This was a 209% increase in density per square meter compared to the fall 2003 sample series. July 2008 recorded 59,267 per square meter; this was an increase of 80% per square meter. Lower Woods Canyon also recorded increases for both the fall 2007 and the spring 2008 samples. The September 2007 samples series recorded 212,752 per square meter, a 239% increase from the previous year's sample. The June 2008 site recorded 127,756 per square meter, a 205% increase from last year's spring sample.

Upper Winter Quarters Canyon recorded increase for both the fall 2007 samples and the spring 2008 samples. In October 2007 Upper Winter Quarters recorded 119,136 per square meter this was a 97% increase from the fall 2003 samples. The July 2008 samples recorded 99,763 per square meter, a 135% increase. Middle Winter Quarters Canyon recorded an increase for both the fall 2007 samples and spring 2008 samples. The October 2007 samples recorded 217,796 per square meter, a 338% increase in density from the fall 2003 sample. The July 2008 sample, however, recorded 107,936 per square meter, a 168% increase. Lower Winter Quarters Canyon recorded increases in density for both the fall 2007 and spring 2008 samples. In October 2007, Lower Winter Quarters recorded 136,740 invertebrates per square meter, a 196% increase from the 2003 sample. The June 2008 sample for this site recorded 124,181 per square meter, a 126% increase.

Table 5. Total invertebrate densities per square meter for Woods and Winter Quarter Canyons

	Shiozawa 2006	Shiozawa 2006	this report	this report
Sampling date	October 2003	June 2004	Sept/Oct 2007	July 2008
Upper Woods Canyon	58804	32949	181813	59267
Lower Woods Canyon	62655	41852	212752	127756
Upper Winter Quarters Canyon	60471	42464	119136	99763
Middle Winter Quarters Canyon	49713	40272	217796	107936
Lower Winter Quarters Canyon	46179	54894	136740	124181

Taxa Specific Densities

In Upper Woods Canyon, the dominant species for the September 2007 samples were: Diptera: Chironomidae (52,222/m^2), Ephemeroptera: early instar (25,251/m^2), Crustacea: *Ostracoda* (25,251/m^2), 29%, 14%, and 14% of the total population, respectively. For the July 2008 samples, the dominant species were: Ephemeroptera: early instar (23,551/m^2), Diptera: Chironomidae (15,177/m^2), and Crustacea: *Ostracoda* (5,026/m^2), 40%, 25%, and 8% of the total population, respectively.

In Lower Woods Canyon, the dominant species for fall 2007 were: Diptera: Chironomidae (119,545/m^2), Crustacea: *Ostracoda* (33,531/m^2), and Crustacea: *Copepoda* (16,146/m^2), 56%, 16%, and 8% of the total population, respectively. For the July 2008 samples, the dominant taxa were: Diptera: Chironomidae (66,891/m^2), Ephemeroptera: early instar (18,979/m^2), and Crustacea: *Ostracoda* (9,302/m^2), 52%, 15%, and7% of the total population, respectively.

The Woods Canyon sites appear to have a good variety of species within them. The following were all found in quantities greater than 500/m^2: *Baetis, Cinygmula, Drunella doddsi, Paraleptophlebia, Zapada, Rhyacophila (larvae), Heterlimnius* (larvae), Ceratopogonidae, *Cheliferia*, Chironomidae *(larva)*, Chironomidae *(pupae), Clinocera, Dicranota, Neoplasta, Pericoma, Simulium, Copepoda, Ostracoda, Hydracarina, Sphaerium sp., Oligochaeta, Planaria*

In Upper Winter Quarters Canyon, the dominant species for October 2007 were: Diptera: Chironomidae (26,797/m^2), Ephemeroptera: early instar (24,463/m^2), and Crustacea: *Copepoda* (23,986/m^2), 22%,21 %, and 20% of the total population, respectively. For the July 2008 samples, the dominant taxa were: Chironomidae (44,018 /m^2), Ephemeroptera: early instar (18,510/m^2), and Ephemeroptera: *Baetis* (11,287/m^2), 44%, 19%, and 11% of the total population, respectively.

In Middle Winter Quarters Canyon, the dominant species for October 2007 were: Diptera: Chironomidae (74,519/m^2), Ephemeroptera: early instar (56,699/m^2), and Crustacea: *Ostracoda* (19,831/m^2), 34%, 26%, and 9% of the total population, respectively. For the July 2008 samples, the dominant taxa were: Diptera: Chironomidae (41,295/m^2), Ephemeroptera: early instar (36,864/m^2), and Ephemeroptera: *Baetis* (5,602/m^2), 38%, 34%, and 5% of the total population, respectively.

In Lower Winter Quarters Canyon, the dominant species for October 2007 were: Diptera: Chironomidae (53,620/m^2), Ephemeroptera: early instar (18,153/m^2), and Ephemeroptera: *Cinygmula* (15,076/m^2), 39%, 13%, and 11% of the total population, respectively. For the July 2008 samples, the dominant taxa were: Diptera: Chironomidae (62,206/m^2), Ephemeroptera: early instar (28,020/m^2), and Ephemeroptera: *Baetis* (21,017/m^2), 50%, 23%, and 17% of the total population, respectively.

Winter Quarters Canyon Creek also recorded a large variety of species, each of the following was found in densities greater then 500/m^2: *Ameletus, Baetis sp., Cinygmula, Drunella doddsi, Drunella grandis, , Ephemerella, Serratella tibialis, Zapada, Micrasema bactro, Rhyacophila, Sweltza, Heterlimnius* (larvae), *Antocha* sp. (Tipulidae), Ceratopogonidae, *Chelifera,* Chironomidae *(larva)*, Chirnomidae (pupae), *Dicranota, Pericoma* (Psychodidae), *Neoplasta, Simulium (larvae), Copepoda, Ostracoda, Hydracarnia, Oligochaeta,* Planaridae.

Biomass

Despite the decreases in number of taxa, the Upper Woods Canyon September 2007 sample biomass increased by 4% (Table7). The Upper Woods Canyon July 2008 sample saw an increase in biomass by 15%. The number of taxa in Lower Woods Canyon in September of 2007 increased from October of 2003as did total invertebrate densities, and but the July 2008 taxa list was considerably lower than the June 2004 taxa estimate. In contrast, the biomass decreased by 54% and 45% respectively.

Of the Winter Quarters sites, only the Middle Winter Quarters July 2008 samples showed an increase in biomass over the 2003-04 samples. The Upper Winter Quarters October 2007 sample was 66% less than the fall 2003 sample. The Upper Winter Quarters July 2008 sample decreased by 11%. Middle Winter Quarters October 2007sample also decreased by 66%. The Lower Winter Quarters station showed a decrease of 18% for October 2007sample while the July 2008 sample decreased by 51%

The Biotic Condition Index

The actual Community Tolerance Quotient (CTQa) was determined from the presence-absence of taxa (Table 8), and was used to generate the Biotic Condition Index (Table 9) for each station. These represent an overall average generated from a list provided by Winget and Mangum (1979) and are based on presence-absence of taxa. Thus a single individual per square meter is equal in weight to another taxa represented by thousands of individuals in the same area. Relative abundance is not considered in this index. It can give us a picture of how conditions have changed over time when compared to previous samples (Table 7) or when adjusted by the ideal (CTQp) for the stream. This adjusted value is the BCI, or Biotic Condition Index.

Table 6. Summary of invertebrate densities by taxa for Woods and Winter Quarter Canyons

	Upper Woods Canyon				Lower Woods Canyon				Upper Winter Quarters Canyon				Middle Winter Quarters Canyon				Lower Winter Quarters Canyon			
Taxa	Oct-03	Jun-04	Sep-07	Jul 08	Oct-03	Jun-04	Sep-07	Jul 08	Oct-03	Jun-04	Oct-07	Jul-08	Oct-03	Jun-04	Oct-07	Jul-08	Oct-03	Jun-04	Oct-07	Jul-08
Ephemeroptera: *Ameletus*			284	38			8	4			170				1049				83	
Ephemeroptera: *Baetis*	1268	2422	6090	928	483	9016	45	3075	9702	4526	939	11287	11139	13514	3757	5602	11940	8643	9798	21017
Ephemeroptera: *Cinygmula*	5822	1049	16945	2110	2460	1148	2409	7579	3778	3087	4814	1988	3110	1127	11541	1905	4248	2267	15067	2390
Ephemeroptera: *Drunella doddsi*	48	23	1916	4	64	21	947	8	152	21	2238	167	258	45	682	129	89	4	686	30
Ephemeroptera: *Drunella grandis*	2			432	4		4	398	2	210		901	76	218	83	549		17	235	515
Ephemeroptera: *Epeorus iron*		32				102				356		220		161		64	23	508		57
Ephemeroptera: early instar *	3008	7316	26433	23551	712	2187	7317	18979	977	1261	24463	18510	2157	4189	56699	36864	2074	20661	18153	28020
Ephemeroptera: *Ephemerella*						4	8		91	4	1401		38	2				2		
Ephemeroptera: *Heptagenia*				23				15						4				8		
Ephemeroptera: *Nixe criddlei*																		4		
Ephemeroptera: *Paraleptophlebia*	13	78	1795	76	199	72	526	231	551	4	269	38	44	186	242	27	32	13	458	4
Ephemeroptera: *Rithrogena*											8									
Ephemeroptera: *Seratella tibialis*		53			2	15			498	1244	364	462	390	568	4174	970	316	364	3492	
Plecoptera: *Alloperla severa*										2				15				15		
Plecoptera: *Classenia sabulosa*														34						
Plecoptera: *Diura knowltoni*																				
Plecoptera: early instar *	4359	1358	4060	515	328	3098	1924	534	354	1596	1951	644	536	737	2102	852	436	1034	3424	564
Plecoptera: *Hesperoperla pacifica*	898	250	258	76	356	191	401	91	32	6	102	27	180	17			62	11		
Plecoptera: *Isocapina*																				
Plecoptera: *Isogenodea*	6																			
Plecoptera: *Isoperla*									8	6			2				6	2		
Plecoptera: *Malenka californica*				34	40	2		473		148		23		379		42				38
Plecoptera: *Megarcys signata*			8								19									
Plecoptera: *Paraperla frontalis*	234			11										195			27			261
Plecoptera:Paragnetina															4					
Plecoptera: *Pteronarcella badia*							8										2	2	11	4
Plecoptera: *Skwalla parallela*	2		27		8				44		80		85	23	114		17		364	

Plecoptera: *Suwallia*		2																8		
Plecoptera: *Sweltza*			341		17		72	4	150	30	526	189	136		1216	640	53	157	973	
Plecoptera: *Zapada*	576	91	3761	49	150	686	1409	34	559	2	235	34	112	133	2617	110	155	314	568	27
Trichoptera: pupae *		8		140		9		30		19		167		36		133	4	28		19
Trichoptera: *Asynarchus*						2														
Trichoptera: *Arctopsyche grandis*	4			61	4							4					2	4		
Trichoptera: Amphicosmoecus																				4
Trichoptera: Brachycentrus		2			89				51		140		133		455		21	13	53	
Trichoptera: Chyranda																				
Trichoptera: Dicosmoecus	65	17	49	95	305	42	38	49	11	40	30	23	208	61	38	136	36	47	68	322
Trichoptera: Dolophilodes gabriella					21													4		
Trichoptera: Hesperophylax						2												2		
Trichoptera: Hydropsyche	2		30		19		379	19	186	2			6		11		667		439	
Trichoptera: Hydorptila											30									
Trichoptera: Lepidostoma	2			4				4												
Trichoptera: Limnephilus										2									8	
Trichoptera: Micrasema					2	2	102	258			186	4			871	38			4	
Trichoptera: Neothremma alicia	19	6	314	140	100	11		163	1263	57		114	487	2		4	70			
Trichoptera: Ocetis	4			4																
Trichoptera: Ochrotrichia						2														
Trichoptera: Oligophlebodes	80	4	481	4	299	8	193	8	1606	244	38		8	462	148		2	17		11
Trichoptera: Parapsyche elsis	15	30	265	15	2		4				80						30			
Trichoptera: Pshychomyia flavida					303				184											
Trichoptera: Rhyacophila (larvae)	1351	307	1326	436	312	324		212		34	216	239	900	131	1254	227	153	85	398	170
Trichoptera: Rhyacophila (pupae)							856													
Trichoptera: Tinodes					17															
Coleoptera: Agabus (adult)																				
Coleoptera: Ampumixis		4																		
Coleoptera: Cleptelmis										4				21				2		
Coleoptera: Dryopidae																				
Coleoptera: Dytiscidae	2	2		68								8						2		4

Coleoptera: Helichus (adult)	2																			
Coleoptera: Heterlimnius (larvae)	600	1297	3242	1651	49	591	3549	1121		4229	5007	3121		3310	4962	1329	25	858	3553	508
Coleoptera: Heterlimnius (adult)	39	68	174	11	8	11	87	11	4	288	553	72		34	212	53	2	53	61	
Coleoptera: Hydrobius										2				2						
Coleoptera: Optioservus (larvae)	177	932	4		1490	1483	167	27	4768	1216	11	34	3948	407	19	4	2791	237	95	8
Coleoptera: Optioservus (adult)	6	6	11	4	47	23	19	38	225	15		61	214		11	38	125	8	53	8
Coleoptera: Microcylleopus										13				4						
Coleoptera: Narpus				4		4	4	30												
Coleoptera: Peltodytes callosus																				
Coleoptera: Hydophilidae						11						4								
Coleoptera: Staphylinidae																4				
Diptera: pupae																				
Diptera: Allognasta						2														
Diptera: Antocha									8				134	27	23		1011	362	1204	345
Diptera: Antocha (pupae)																				49
Diptera: Atherix	6				2						27				4			4		
Diptera: Caloparyphus						25	19	27			8			17	182	133		28	49	30
Diptera: Canace macateei																				
Diptera: Ceratopogonidae	816	595	928	269	1134	250	2420	1420	2850	882	1595	1125	828	371	1375	1045	473	76	667	246
Diptera: Chelifera	2	4	572		142		621	8	121		15		93		557		256	2	1276	
Diptera: Chironomidae (larvae)	18332	4259	52222	15177	25408	5568	119545	66891	13519	8999	26797	44018	14063	4075	74519	41295	13896	8440	53620	62206
Diptera: Chironomidae (pupae)		6	182	265	13	186	754	712	4	2	87	455	203	2	818	818	261	64	390	1458
Diptera: Chyrsops		2																		
Diptera: Clinocera			34				879	11							8	4	81			
Diptera: Dicranota	4	4	602	19			61	8	80	8	242	45	55	2	87	49	70	104	674	34
Diptera: Dixa		8				9							2						114	
Diptera: Euparyphus	2	2			34	2	4	4		8					27				45	8
Diptera: Hemerodromia (larvae)	15				9	2					15		110	2						
Diptera: Hemerodromia (pupae)		6				2								2						
Diptera: Hexatoma	13																		8	
Diptera: Limnophila			292	53			15	11			4	4			4	8				4

Diptera: Limnophora			5				19								8				11	
Diptera: Molophilus																				
Diptera: Neoplasta							553	405				4				27				587
Nr. Rhabdomstix				15															4	
Pedica								30												
Diptera: Pericoma	158		1326	4	655		1939		2937		477		1964		1507		466		739	
Diptera: Ptychoptera	52		383	4	6		15									4			30	4
Rhyamphomyia																				
Scleroptrocta tetonica			4	8			4	11												4
Diptera: Simulium (larvae)	444	62	492	27	337		1898	477	538	142	30	216	773	763	455	3507	163	5183	155	860
Diptera: Simulium (pupae)				4										4				184		4
Diptera: Tipula	857	80	64	8	44	21	53	19	165	6	4	27	8	4	23		335	8	8	
Crustacea: Cladocera	4				8	114	4		195					57						
Crustacea: Copepoda	5668	5056	20358	4821	5901	3352	16146	5825	3818	3189	23986	4352	2121	1988	18786	2511	687	114	3689	348
Crustacea: Isopoda														68						
Crustacea: Ostracoda	10811	3642	25251	5026	14423	9168	33531	9302	5863	4401	12438	4280	3490	3653	19831	4859	1364	1197	6208	2030
Arachnida: Hydracarina	2554	2163	9310	1985	3547	2333	10745	5291	2259	2449	4787	4753	1526	1375	6605	2352	2714	1663	4412	1432
Mollusca: Sphaerium	26	102	144		909	125	27		2858	833	148		165	184	473	4	172		242	227
Mollusca: Gyraulus		6				2												246		
Columella																				
Mollusca: Lymai														2						
Collembola	199		466					348		76		117		174		8		2	114	
Haplotaxidae (Oligochaeta)																				
Annelida: Oligochaeta	286	865	1117	845	2180	1415	2867	2901	62	1507	3935	1136	8	970	1273	1223	822	1763	4954	311
Lepidoptera				4	9			15		2		11		4						8
Turbellaria: Planariidae		106	530	292		208	129	648		1309	398	882		68	19	193		108	167	
Nematoda *		625												515						
Hemiptera: Corixidae																				

Table 7. Biomass in grams for Woods and Winter Quarter Canyons

	Upper Woods Canyon				Lower Woods Canyon				Upper Winter Quarters Canyon				Middle Winter Quarters Canyon				Lower Winter Quarters Canyon			
Sample	Oct-03	Jun-04	Sep-07	Jul-08	Oct-03	Jun-04	Sep-07	Jul-08	Oct-03	Jun-04	Oct-07	Jul-08	Oct-03	Jun-04	Oct-07	Jul-08	Oct-03	Jun-04	Oct-07	Jul-08
1	1.82	2.33	1.383	5.785	7.15	2.483	1.705	1.268	4.538	2.001	0.118	3.388	6.967	1.707	2.149	1.194	2.817	2.023	1.573	2.577
2	0.939	2.212	2.749	3.831	3.31	3.304	0.298	1.612	2.015	1.147	0.993	3.375	2.567	1.895	0.971	13.614	2.368	2.502	2.399	2.685
3	4.08	1.16	2.541	1.849	1.46	2.872	2.193	2.016	2.849	3.822	1.964	3.114	1.878	2.468	1.467	5.479	1.759	6.534	1.401	3.53
4	1.36	1.123	2.001	1.935	2	4.648	0.739	1.898	4.689	6.752	0.615	2.376	6.938	3.169	1.306	4.031	1.985	4.162	1.227	2.881
5	2.02	1.879	2.775	2.879	4.08	5.067	0.898	1.674	2.331	3.505	1.258	2.533	8.798	2.757	2.248	2.724	2.409	4.557	1.318	2.285
6	2.31	1.538	1.594	0.679	2.91	6.017	1.649	1.203	3.504	2.935	0.838	2.133	1.008	3.106	0.972	2.771	2.276	5.653	1.793	1.523
7	-	2.062	2.003	0.662	1.42	2.04	2.768	1.083	3.604	2.116	1.081	3.514	2.996	5.374	1.295	2.931	1.635	12.17	3.688	4.813
8	-	3.956	2.365	1.119	3.77	3.765	1.641	5.853	3.841	2.576	2.405	1.759	4.332	7.205	1.603	2.667	4.668	8.13	2.907	2.045
total	12.53	16.25	17.41	18.74	26.1	30.2	11.89	16.61	27.37	24.85	9.27	22.19	35.47	27.68	12.01	35.41	19.97	45.73	16.31	22.34
per m^2	31.64 g/m^2	30.78 g/m^2	32.98 g/m2	35.49 g/m2	49.43 g/m2	57.19 g/m^2	22.52 g/m2	31.45 g/m2	51.82 g/m^2	47.07 g/m^2	17.56 g/m2	42.03 g/m2	67.18 g/m^2	52.43 g/m^2	22.75 g/m2	67.06 g/m2	37.72 g/m^2	86.60 g/m^2	30.88 g/m2	42.31 g/m2

* Each sample is actually 2 samples from one riffle. Therefore total biomass was divided by 2 before calculation of the density in g/m^2

Table 8. Tolerance quotients for Woods and Winter Quarter Canyons

Taxa	Upper Woods Sept 2007	Lower Woods Sept 2007	Upper WQ Oct 2007	Middle WQ Oct 2007	Lower WQ Oct 2007	Upper Woods July 2008	Lower Woods July 2008	Upper WQ July 2008	Middle WQ July 2008	Lower WQ July 2008	Ideal stream
Ephemeroptera: Ameletus	48	48	48	48	48	48	48				48
Ephemeroptera: Baetidae: Baetis sp.	72	72	72	72	72	72	72	72	72	72	72
Ephemeroptera: early instar *	72	72	72	72	72	72	72	72	72	72	72
Ephemeroptera: Ephemerellidae: Drunella doddsi	4	4	4	4	4	4	4	4	4	4	4
Ephemeroptera: Ephemerellidae: Drunella grandis		24		24	24	24	24	24	24	24	24
Ephemeroptera: Ephemerellidae: Ephemerella		48	48								48
Ephemeroptera: Ephemerellidae: Seratella tibialis			24	24	24			24	24		24
Ephemeroptera: Heptageniidae: Cinygmula	21	21	21	21	21	21	21	21	21	21	21
Ephemeroptera: Heptageniidae: Epeorus iron								21	21	21	21
Ephemeroptera: Heptageniidae: Heptagenia						48	48				48
Ephemeroptera: Heptageniidae: Nixe criddlei											48
Ephemeroptera: Heptageniidae: Rithrogena			21								21
Ephemeroptera: Leptophlebiidae: Paraleptophlebia	24	24	24	24	24	24	24	24	24	24	24
Plecoptera: Capniidae: Isocapina											24
Plecoptera: Chloroperlidae: Alloperla severa											24
Plecoptera: Chloroperlidae: Paraperla frontalis						24				24	24
Plecoptera: Paragnetina				24							24
Plecoptera: Chloroperlidae: Suwallia											24
Plecoptera: Chloroperlidae: Sweltza	24	24	24	24	24		24	24	24		24
Plecoptera: early instar *	36	36	36	36	36	36	36	36	36	36	36
Plecoptera: Nemouridae: Malenka californica						36	36	36	36	36	36
Plecoptera: Nemouridae: Zapada	16	16	16	16	16	16	16	16	16	16	16
Plecoptera: Perlidae: Classenia sabulosa											6
Plecoptera: Perlidae: Hesperoperla pacifica	18	18	18			18	18	18			18
Plecoptera: Perlodidae: Diura knowltoni											24
Plecoptera: Perlodidae: Isogenoides											24
Plecoptera: Perlodidae: Isoperla											48
Plecoptera: Perlodidae: Megarcys signata	24		24								24
Plecoptera: Perlodidae: Skwalla parallela	18		18	18	18						18
Plecoptera: Pteronarcyidae: Pteronarcella badia		24			24					24	24
Trichoptera: pupae *						108	108	108	108	108	108
Trichoptera: Amphicomoecus										18	18
Trichoptera: Brachycentridae: Brachycentrus			24	24	24						24
Trichoptera: Brachycentridae: Micrasema		24	24	24	24		24	24	24		24
Trichoptera: Hydroptilidae: Hydorptila			108								108
Trichoptera: Hydroptilidae: Ochrotrichia											108
Trichoptera: Hydropsychidae: Arctopsyche grandis						18		18			18
Trichoptera: Hydropsychidae: Hydropsyche	108	108		108	108		108				108
Trichoptera: Hydropsychidae: Parapsyche elsis	6	6	6			6					6

Trichoptera: Lepidostomatidae: Lepidostoma						18	18				18
Trichoptera: Leptoceridae: Ocetis						54					54
Trichoptera: Limnephilidae: Asynarchus											108
Trichoptera: Limnephilidae: Chyranda											18
Trichoptera: Limnephilidae: Dicosmoecus	24	24	24	24	24	24	24	24	24	24	24
Trichoptera: Limnephilidae: Hesperophylax											108
Trichoptera: Limnephilidae: Limnephilus					108						108
Trichoptera: Philopotamidae: Dolophilodes gabriella											24
Trichoptera: Psychomyidae: Tinodes											108
Trichoptera: Rhyacophilidae: Rhyacophila	18	18	18	18	18	18	18	18	18	18	18
Trichoptera: Uenoidae: Neothremma alicia	8			8		8	8	8	8		8
Trichoptera: Uenoidae: Oligophlebodes	24	24	24	24		24	24			24	24
Coleoptera: Dryopidae: Helichus											54
Coleoptera: Dytiscidae						72		72		72	72
Coleoptera: Dytiscidae: Agabus					.						72
Coleoptera: Elmidae: Ampumixis											108
Coleoptera: Elmidae: Cleptelmis											108
Coleoptera: Elmidae: *Heterlimnius*	108	108	108	108	108	108	108	108	108	108	108
Coleoptera: Elmidae: Microcylleopus											108
Coleoptera: Elmidae: Narpus		108				108	108				108
Coleoptera: Elmidae: Optioservus	108	108	108	108	108	108	108	108	108	108	108
Coleoptera: Haliplidae: Peltodytes callosus											54
Coleoptera: Hydrophilidae								72			72
Coleoptera: Hydrophilidae: Hydrobius											72
Coleoptera: Staphylinidae									108		108
Diptera: pupae *											108
Diptera: Athericidae: Atherix			24	24							24
Diptera: Canacidae: Canace macateei											108
Diptera: Ceratopogonidae	108	108	108	108	108	108	108	108	108	108	108
Diptera: Chironomidae	108	108	108	108	108	108	108	108	108	108	108
Diptera: Dixidae: Dixa					108						108
Diptera: Empididae: Chelifera	108	108	108	108	108		108				108
Diptera: Empididae: Hemerodromia			108								108
Diptera: Muscidae: Limnophora	108	108		108	108						108
Diptera: Empididae: Neoplasta		108					108	108	108	108	108
Diptera: Pedica							24				24
Diptera: Psychodidae: Pericoma	36	36	36	36	36	36					36
Diptera: Ptychopteridae: Ptychoptera	108	108			108	108			108	108	108
Diptera: Simuliidae: Simulium	108	108	108	108	108	108	108	108	108	108	108
Diptera: Stratomyidae: Allognasta											108
Diptera: Stratiomyidae: Caloparyphus		108	108	108	108		108		108	108	108
Diptera: Stratiomyidae: Euparyphus		108		108	108		108			108	108
Diptera: Tipulidae: Antocha				24	24					24	24
Diptera: Tabanidae: Chyrsops											108
Diptera: Tipulidae: Dicranota	24	24	24	24	24	24	24	24	24	24	24

Diptera: Tipulidae: Limnophila	72	72	72	72		72	72	72	72	72	72
Diptera: Tipulidae: Hexatoma					36						36
Diptera: Tipulidae: Tipula	36	36	36	36	36	36	36	36			36
Diptera: Empididae:Clinocrea		108		108			108		108		108
Diptera: Limoniidae: Nr. Rhabdomastix					108	108					108
Diptera: Scleroprocta tetonica	72	72				72	72			72	72
Crustacea: Cladocera		108									108
Crustacea: Copepoda	108	108	108	108	108	108	108	108	108	108	108
Crustacea: Isopoda											108
Crustacea: Ostracoda	108	108	108	108	108	108	108	108	108	108	108
Arachnida: Hydracarina	108	108	108	108	108	108	108	108	108	108	108
Mollusca: Lymnaidae: Lymai											108
Mollusca: Planoribidae: Gyraulus											108
Mollusca: Sphaeriidae: Sphaerium	108	108	108	108	108				108	108	108
Annelida: Oligochaeta	108	108	108	108	108	108	108	108	108	108	108
Tricladida: Planariidae	108	108	108	108	108	108	108	108	108		108
Collembola	108				108		108	108	108		108
Hemiptera: Corixidae											108
Lepidoptera						72	72	72		72	72
Nematoda *											108
Total	2425	3035	2402	2581	2921	2509	2911	2236	2488	2414	6847
N	38	45	41	42	43	42	44	37	36	37	104
CTQa	63.82	67.44	58.59	61.45	67.93	59.74	66.16	60.43	69.11	65.24	65.83

Community Tolerance Quotient and Biotic Condition Indices

The CTQp values are estimated from a combination of gradient, substrate, and water chemistry in accordance with a key provided by Winget and Mangum (1979). The Biotic Condition Index is the ratio of CTQp/CTQa expressed as a percent. This ratio effectively reverses the reading of the relationships so that instead of low values being indicative of higher quality waters, high BCI values indicate better water quality. The ideal is a BCI of 100 or higher, meaning that the station meets or exceeds the predicted level.

Each of the stations recorded both excellent CTQa (<65) and BCI (>85) index values. In general fall sampling periods tend to have great BCI and lower CTQa than the spring sampling periods.

For the fall samples, Upper Winter Quarters had the greatest BCI value (137) followed by Middle Winter Quarters (130), Upper Woods Canyon (125), Lower Woods Canyon (119) and Lower Winter Quarters (118). With 100 being a good value, we can assume excellent conditions for these streams. Among the spring samples, Upper Winter Quarters had the greatest BCI value (134) followed by Upper Winter Quarters (132), Lower Winter quarters (123), Lower Woods Canyon (121), and Middle Winter Quarters (110). The extremely high BCI and relatively low CTQa indicate that the streams have high quality habitat.

Table 9. CTQa and BCI values for Woods and Winter Quarter Canyons

	Shiozawa 2004	Shiozawa 2004	this report	this report
Sampling date	Oct 2003	June 2004	Sept/Oct 2007	July 2008
	CTQa / BCI	CTQa / BCI	CTQa / BCI	CTQa / BCI
Upper Woods Canyon	61/131	68/ 117	64/125	60/ 134
Lower Woods Canyon	60/134	73/ 110	67/119	66/ 121
Upper Winter Quarters Canyon	58/ 139	67/ 121	59/ 137	60/ 132
Middle Winter Quarters Canyon	58/139	66/ 122	61/130	69/ 116
Lower Winter Quarters Canyon	55/ 145	61/ 133	68/118	65/ 123
Average	58/ 138	67/ 121	64/ 126	64/ 125

Diversity Indices

Diversity indices combine both number of taxa and relative densities into a single measurement. High diversity index values indicate more taxa and an even number of individuals per taxon. Low diversity values generally reflect a depauperate fauna in species and a very skewed distribution in numbers per taxon. Usually a low diversity community will be dominated by just a few taxa with other taxa being rare and in low density.

The fall 2007 Upper Woods Canyon sample recorded an index of 2.153, a 5% increase from fall 2003. The July 2008 sample however, decreased 16% from 2.327 to 1.957. The Lower Woods Canyon September 2007 sample diversity index was 1.532 a 21% decrease from the fall 2003 sample. The July 2008 sample decreased 23% from 2.153 (spring 2004) to 1.648.

The Upper Winter Quarters October 2007 sample diversity index was 2.135, a 15% decrease from the previous year. The July 2008 sample recorded a value of 1.718, a 30% decrease. The Middle Winter Quarters October 2007 sample recorded an index of 1.983, a 12% percent decrease. The July 2008 sample showed a decrease of 24% over last year's value. Lower Winter Quarters October 2007 recorded an index of 2.057, a 3% percent decrease. The July sample decreased to 1.208, a 44% decrease.

A slight seasonal pattern of higher diversities in the fall occurs with the 2007-08 data sets. This is despite fall 2007 diversity values at most sites being lower than recorded in the fall of 2003.

Table 10. Diversity indices, based on natural logs, for Woods and Winter Quarter Canyons

	Shiozawa 2004	Shiozawa 2004	this report	this report
Sampling date	Oct 2003	June 2004	Sept/Oct 2007	July 2008
Upper Woods Canyon	2.041	2.327	2.153	1.957
Lower Woods Canyon	1.930	2.153	1.532	1.648
Upper Winter Quarters Canyon	2.518	2.447	2.135	1.718
Middle Winter Quarters Canyon	2.250	2.240	1.983	1.703
Lower Winter Quarters Canyon	2.125	2.139	2.057	1.208

Cluster Analysis

The cluster analysis of the data utilizes the Bray-Curtis dissimilarity index (Poole 1974, Krebs 1989) with the unweighted pairs group averaging algorithm (UPGMA) (NTSYS; Rolf 2000). The analysis (Figure 1) resulted in two principle clusters separating at a dissimilarity value of 76. The top cluster, cluster 1 for reference, contained all of the fall 2002 sites for both Woods Canyon Creek and Winter Quarters Creek as well as the three Winter Quarters Canyon sample stations from the spring of 2005. The lower cluster, cluster 2, contained all of the 2003, 2004, 2007 and 2008 sites. Within cluster 2, two subclades exist, separating at about 60% dissimilarity. The upper one is mostly comprised of fall 2003 and spring 2004 samples. The second subclade includes the fall 2004 and the majority of both fall 2007 and spring 2008 samples. The sites show tendencies to be grouped by site and sampling date. These trends are likely reflecting both seasonal changes in the community structure and annual variations in weather conditions (e.g. wet years and dry years). As such they are generating a good baseline signal for future studies.

Figure 1. UPGMA Cluster dendrogram of relationships among communities from Woods and Winter Quarters Canyons.

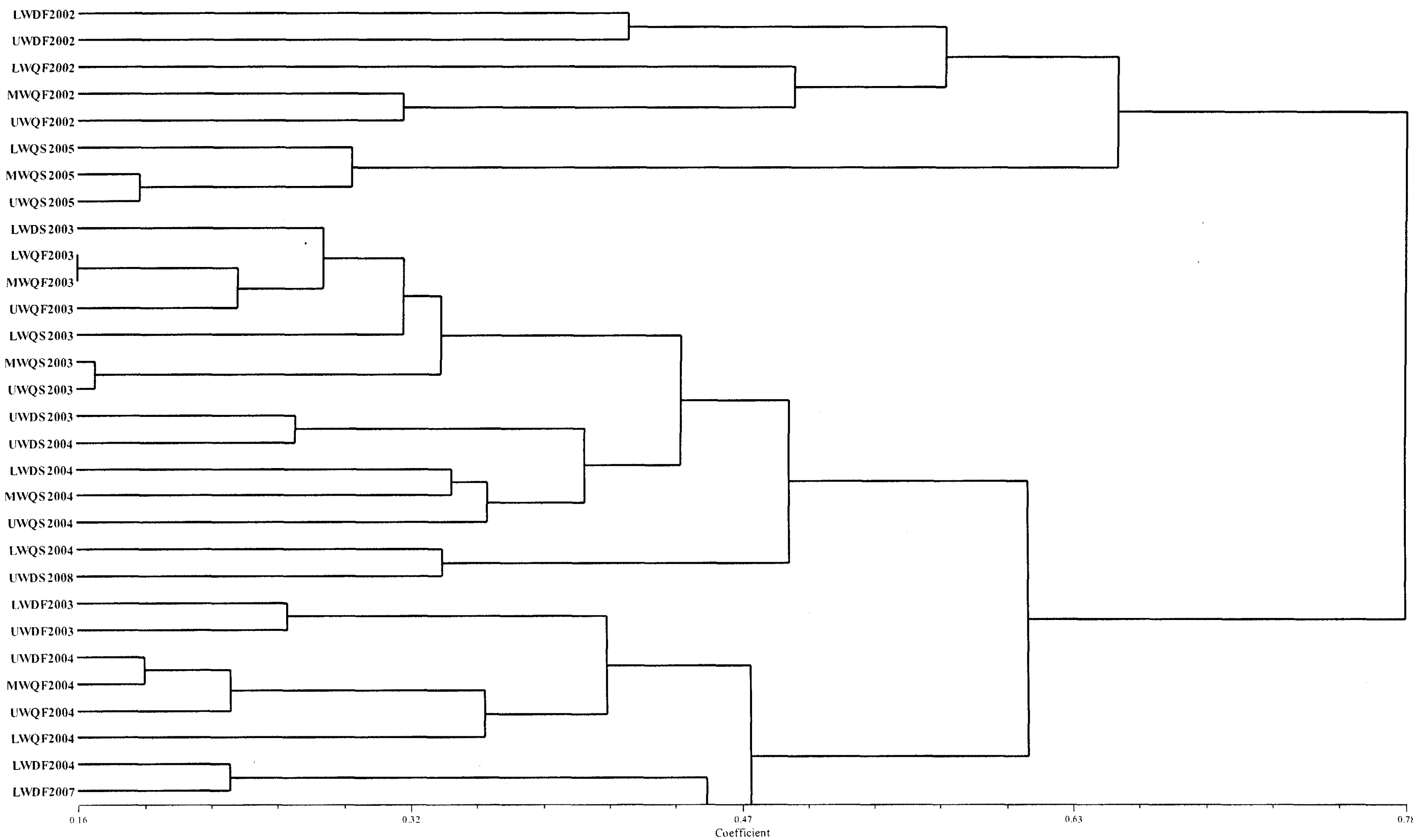
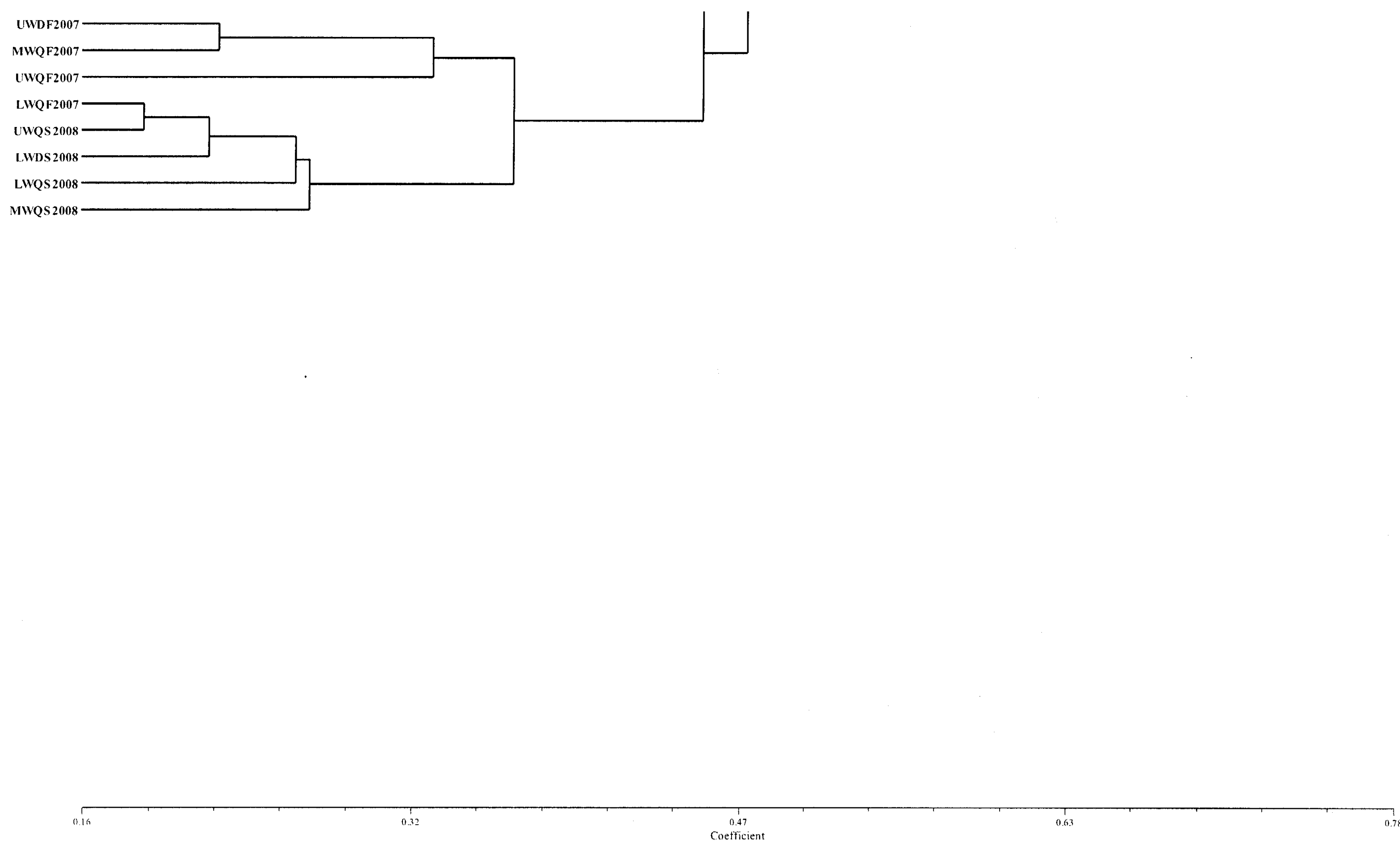


Figure 1. (cont).



Conclusions

Several generalizations can be made from these samples. Woods Canyon and Winter Quarters Canyon samples differed in the trends with their number of taxa. The Woods taxa counts in the fall were lower than the fall of 2003 while the spring Woods counts were higher than in the spring of 2004. Winter Quarters showed the opposite trend with the number of taxa increasing in the fall of 2007 relative to the fall of 2003 and decreasing in the spring of 2008 relative to the number of taxa in the spring of 2004. It is not clear why such different trends would be occurring between the two streams.

Total invertebrate densities in all five stations for both seasons showed an increase over the 2003-2004 samples. Yet the biomass in most stations decreased. This suggests a shift to smaller taxa, and is reflected in the high increase in the numbers of midges collected. While we did not quantify algae, we did notice a significant increase in algae, especially in the July 2008 sampling period, but also to a lesser extent in fall, 2007. These blooms were notable in the open areas where sunlight was readily reaching the stream bed. This could be one factor shifting the 2007 and 2008 samples into their own subclade in the cluster analysis.

The Biotic Condition Index and Community Tolerance Quotient did not detect any differences between stations. Diversity indices generally showed a decline in stream quality at the majority of stations, and this decrease was likely a reflection of the increase in the number of midges in the samples since high numbers of a few taxa will increase the uneveness of the proportions used in the computation of the index.

Only the Spring 2008 Upper Winter Quarters station had a large shift in hardness as compared to previous samples. Yet this site was similar to the other Winter Quarters stations in the decreased number of taxa and increased total density. It also had the same taxa dominating abundance as in the other spring 2008 Winter Quarters samples and both biomass and diversity were similar to the other Winter Quarters stations. Interestingly the only other measure that identified a significant difference in the Upper Winter Quarters was in the cluster analysis. Cluster analysis is based on comparisons of individual taxa across sites so the net effect of community differences in the less abundant taxa can have in influence. This suggests that the species composition in the Upper Winter Quarters spring 2008 samples more closely resembled that in the spring 2004 Lower Winter Quarters station. This station, while still having elevated numbers of midges, also is in a heavily shaded reach with conifers on both sides of the stream channel. The invertebrate community may not have been as strongly impacted by algal growth as other sections, and thus remained more closely associated with the spring 2004 samples.

While these samples are still documenting the pre-mining subsidence conditions of the two streams, interesting variation is being detected. This could be associated with things such as stream-side grazing, increased surface runoff, and other environmental factors. What is developing now is a picture of the background variation in the watersheds upon which the post subsidence communities can be appraised.

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Appendix A. Sample data and invertebrates per square meter for Woods Canyon (Fall 2007).

	Upper Woods Canyon*								Lower Woods Canyon								
Taxa	1	2	3	4	5	6	8	**# / m^2**	1	2	3	4	5	6	7	8	# / m2
Ephemeroptera: Baetis	154	180	56	30	163	3	0	**1268**	48	37	10	2	135	15	5	3	**483**
Ephemeroptera: Cinygmula	124	517	437	69	256	987	300	**5822**	85	224	295	169	15	15	219	187	**2460**
Ephemeroptera: Drunella doddsi	6	1	1	5	3	6	0	**48**	1	6	3	2	10	5	3	4	**64**
Ephemeroptera: Drunella grandis	0	0	0	0	0	1	0	**2**	1	0	0	1	0	0	0	0	**4**
Ephemeroptera: early instar**	120	84	2	26	176	607	375	**3008**	31	32	243	3	62	0	0	5	**712**
Ephemeroptera: Paraleptophlebia	0	0	3	2	0	1	0	**13**	17	51	10	0	12	11	0	4	**199**
Ephemeroptera: Seratella tibialis	0	0	0	0	0	0	0	**0**	0	1	0	0	0	0	0	0	**2**
Plecoptera: early instar**	31	84	0	43	693	713	450	**4359**	4	33	5	35	76	0	1	19	**328**
Plecoptera: Hesperoperla pacifica	35	8	10	154	24	34	150	**898**	16	30	75	20	30	0	5	12	**356**
Plecoptera: Isogenodea	0	0	3	0	0	0	0	**6**	0	0	0	0	0	0	0	0	**0**
Plecoptera: Malenka californica	0	0	0	0	0	0	0	**0**	0	0	0	0	0	21	0	0	**40**
Plecoptera: Paraperla	26	12	28	23	10	9	0	**234**	0	0	0	0	0	0	0	0	**0**
Plecoptera: Pteronuarcella badia	0	0	0	0	0	0	0	**0**	0	1	0	0	0	0	1	0	**4**
Plecoptera: Skwalla parallela	0	0	0	0	0	1	0	**2**	2	0	1	0	0	0	1	0	**8**
Plecoptera: Sweltza	0	0	0	0	0	0	0	**0**	2	0	2	0	2	3	0	0	**17**
Plecoptera: Zapada	28	88	92	11	19	28	0	**576**	7	20	5	26	21	0	0	0	**150**
Trichoptera: Arctopsyche grandis	0	0	0	0	0	2	0	**4**	0	0	0	2	0	0	0	0	**4**
Trichoptera: Brachycentrus	0	0	0	0	0	0	0	**0**	0	2	1	0	1	0	7	36	**89**
Trichoptera: Dicosmoecus	0	0	15	0	0	0	15	**65**	30	4	0	0	127	0	0	0	**305**
Trichoptera: Dolophilodes gabriella	0	0	0	0	0	0	0	**0**	0	0	0	0	0	11	0	0	**21**
Trichoptera: Hydropsyche	0	1	0	0	0	0	0	**2**	1	1	0	0	5	0	1	2	**19**
Trichoptera: Lepidostoma	1	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Trichoptera: Micrasema	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	1	0	**2**

Trichoptera: Neothremma alicia	0	1	0	2	5	1	0	**19**	.32	1	1	1	9	0	2	7	**100**
Trichoptera: Oecetis	0	0	1	1	0	0	0	**4**	0	0	0	0	0	0	0	0	**0**
Trichoptera: Oligophlebodes	1	4	6	10	5	11	0	**80**	4	4	7	0	73	8	53	9	**299**
Trichoptera: Parapsyche elsis	3	1	2	0	1	0	0	**15**	0	0	0	1	0	0	0	0	**2**
Trichoptera: Rhyacophila	38	1	13	12	350	201	0	**1351**	6	80	4	19	194	0	17	5	**615**
Trichoptera: Tinodes	0	0	0	0	0	0	0	**0**	0	1	0	0	0	8	0	0	**17**
Coleoptera: Dytiscidae (larvae)	1	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Coleoptera: Helichus (adult)	1	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Coleoptera: Heterlimnius (larvae)	4	224	22	0	0	27	0	**600**	0	0	0	1	0	0	0	25	**49**
Coleoptera: Heterlimnius (adult)	10	3	2	0	0	3	0	**39**	0	0	0	1	0	0	0	3	**8**
Coleoptera: Optioservus (larvae)	0	0	0	11	20	51	0	**177**	133	166	36	16	249	64	13	110	**1490**
Coleoptera: Optioservus (adult)	0	0	0	1	2	0	0	**6**	3	3	2	0	17	0	0	0	**47**
Diptera: Atherix	0	3	0	0	0	0	0	**6**	0	0	0	1	0	0	0	0	**2**
Diptera: Ceratopogonidae	1	42	2	6	2	150	150	**764**	29	22	15	3	469	15	0	46	**1134**
Diptera: Chelifera	0	1	0	0	0	0	0	**2**	33	34	5	0	3	0	0	0	**142**
Diptera: Chironomidae (larvae)	596	1230	297	1745	1287	1265	1950	**18332**	3215	3211	1879	44	1921	142	1119	1886	**25408**
Diptera: Chironomidae (pupae)	0	0	0	0	0	0	0	**0**	3	0	2	0	1	0	0	1	**13**
Diptera: Dicranota	0	0	2	0	0	0	0	**4**	0	0	0	0	0	0	0	0	**0**
Diptera: Euparyphus	0	0	0	1	0	0	0	**2**	3	3	2	0	6	0	3	1	**34**
Diptera: Hemerodromia	0	0	0	1	6	0	0	**15**	0	0	0	1	0	4	0	0	**9**
Diptera: Hexatoma	0	4	2	0	0	0	0	**13**	0	0	0	0	0	0	0	0	**0**
Diptera: Pericoma	5	55	5	0	7	1	0	**158**	59	74	80	6	63	15	13	35	**655**
Diptera: Ptychoptera	3	11	0	8	2	0	0	**52**	0	0	0	0	0	0	0	3	**6**
Diptera: Simulium	66	1	48	1	8	6	75	**444**	8	72	4	1	90	1	1	1	**337**
Diptera: Tipula	1	1	0	4	2	163	225	**857**	3	3	0	3	5	3	4	2	**44**
Crustacea: Cladocera	0	0	0	1	1	0	0	**4**	0	1	0	0	0	0	0	3	**8**

Crustacea: Copepoda	90	120	80	1050	304	600	375	**5668**	914	395	787	1	408	11	150	450	**5901**
Crustacea: Ostracoda	62	200	11	902	1053	452	2325	**10811**	2093	1442	1299	0	1126	6	900	750	**14423**
Arachnida: Hydracarina	31	0	241	154	150	154	450	**2554**	345	365	39	0	217	2	151	754	**3547**
Mollusca: Sphaerium	0	2	3	5	1	1	0	**26**	36	101	106	0	215	10	8	4	**909**
Annelida: Oligochaetea	0	0	44	0	8	5	75	**286**	1	1	1	5	1	81	175	886	**2180**
Collembola	90	0	0	0	2	0	0	**199**	0	0	0	0	0	0	0	0	**0**
Lepidoptera	0	0	0	0	0	0	0	**0**	0	0	0	1	0	0	0	4	**9**
Totals	1528	2879	1428	4278	4560	5483	6915		7165	6421	4919	365	5563	451	2853	5257	

* The data for riffle 7 of upper Woods was lost. Calculations are based on the other 7 riffles. ** Not included in total taxa counts or calculations for diversity

Appendix B. Sample data and invertebrates per square meter for Woods Canyon (Spring 2008).

	Upper Woods Canyon									Lower Woods Canyon								
Taxa	1	2	3	4	5	6	7	8	**# / m^2**	1	2	3	4	5	6	7	8	**# / m2**
Ephemeroptera: Baetis	159	125	129	221	228	77	280	60	**2422**	574	579	949	375	1103	369	282	530	**9016**
Ephemeroptera: Cinygmula	137	81	42	45	65	55	91	38	**1049**	91	58	98	83	57	81	75	63	**1148**
Ephemeroptera: Drunella doddsi	0	3	0	3	0	2	2	2	**23**	0	0	2	0	1	5	1	2	**21**
Ephemeroptera: Epeorus iron	1	0	0	3	6	1	5	1	**32**	3	1	9	1	5	24	3	8	**102**
Ephemeroptera: early instar *	150	790	665	482	512	873	211	180	**7316**	158	100	185	155	184	160	122	91	**2187**
Ephemeroptera: Ephemerella	0	0	0	0	0	0	0	0	**0**	0	0	0	0	2	0	0	0	**4**
Ephemeroptera: Paraleptophlebia	0	0	4	0	2	34	0	1	**78**	2	2	1	0	31	2	0	0	**72**
Ephemeroptera: Seratella tibialis	1	7	2	5	5	3	1	4	**53**	2	2	1	0	1	2	0	0	**15**
Plecoptera: early instar *	184	186	12	94	66	36	103	36	**1358**	334	150	375	193	257	160	91	76	**3098**
Plecoptera: Hesperoperla pacifica	5	21	36	13	15	19	11	12	**250**	12	9	12	13	17	18	5	15	**191**
Plecoptera: Malenka californica	0	0	0	0	0	0	0	0	**0**	0	0	0	0	1	0	0	0	**2**
Plecoptera: Suwallia	0	0	0	0	0	1	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Plecoptera: Zapada	0	1	1	0	0	6	6	34	**91**	30	42	92	0	36	128	30	4	**686**
Trichoptera: pupae *	0	0	0	0	3	1	0	0	**8**	0	0	0	0	2	3	0	0	**9**
Trichoptera: Asynarchus	0	0	0	0	0	0	0	0	**0**	0	0	0	0	1	0	0	0	**2**
Trichoptera: Brachycentrus	0	0	0	0	0	1	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Trichoptera: Dicosmoecus	3	0	0	0	0	0	0	6	**17**	0	7	1	4	1	8	0	1	**42**
Trichoptera: Hesperophylax	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	1	**2**
Trichoptera: Micrasema	0	0	0	0	0	0	0	0	**0**	0	0	0	0	1	0	0	0	**2**
Trichoptera: Neothremma alicia	0	0	0	2	0	0	1	0	**6**	3	1	0	2	0	0	0	0	**11**
Trichoptera: Ochrotrichia	0	0	0	0	0	0	0	0	**0**	1	0	0	0	0	0	0	0	**2**
Trichoptera: Oligophlebodes	0	0	1	0	1	0	0	0	**4**	0	0	0	0	0	3	0	1	**8**
Trichoptera: Parapsyche elsis	1	1	0	0	7	3	3	1	**30**	0	0	0	0	0	0	0	0	**0**
Trichoptera: Rhyacophila	9	13	22	18	42	22	22	14	**307**	38	15	12	11	65	14	8	8	**324**

Coleoptera: Ampumixis	0	0	0	0	0	2	0	0	**4**	0	0	0	0	0	0	0	0	**0**
Coleoptera: Dytiscidae	0	1	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Coleoptera: Heterlimnius (larvae)	80	150	26	101	43	47	97	141	**1297**	22	7	42	36	16	53	85	51	**591**
Coleoptera: Heterlimnius (adult)	1	1	0	0	0	33	0	1	**68**	0	2	1	0	0	3	0	0	**11**
Coleoptera: Hydrobius	0	0	0	0	0	0	0	0	**0**	3	0	0	1	2	0	0	0	**11**
Coleoptera: Narpus	0	0	0	0	0	0	0	0	**0**	0	0	1	0	0	0	1	0	**4**
Coleoptera: Optioservus (larvae)	12	82	63	139	3	34	88	71	**932**	92	55	154	80	86	56	118	142	**1483**
Coleoptera: Optioservus (adult)	0	0	0	1	0	2	0	0	**6**	3	2	1	1	0	2	0	3	**23**
Diptera: Allognasta	0	0	0	0	0	0	0	0	**0**	1	0	0	0	0	0	0	0	**2**
Diptera: Caloparyphus	0	0	0	0	0	0	0	0	**0**	5	1	2	1	0	1	3	0	**25**
Diptera: Ceratopogonidae	90	61	37	32	1	1	61	33	**598**	1	7	31	0	33	0	0	62	**254**
Diptera: Chelifera	0	0	0	0	0	0	0	2	**4**	0	0	0	0	0	0	0	0	**0**
Diptera: Chironomidae (larvae)	233	263	396	315	208	315	260	259	**4259**	373	567	221	346	258	295	67	813	**5568**
Diptera: Chironomidae (pupae)	0	0	0	0	0	2	1	0	**6**	30	2	0	30	1	0	1	34	**186**
Diptera: Chrysops	0	1	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	**0**
Diptera: Dicranota	2	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	**0**
Diptera: Dixa	1	0	1	0	1	0	1	0	**8**	1	0	0	0	2	1	0	1	**9**
Diptera: Euparyphus	0	0	0	0	0	0	1	0	**2**	0	0	0	0	0	0	1	0	**2**
Diptera: Hemerodromia (larvae)	0	0	0	0	0	0	0	0	**0**	0	0	0	1	0	0	0	0	**2**
Diptera: Hemerodromia (pupae)	1	0	1	0	0	1	0	0	**6**	0	1	0	0	0	0	0	0	**2**
Diptera: Simulium	0	3	0	0	30	0	0	0	**62**	0	0	0	0	0	0	0	0	**0**
Diptera: Tipula	2	0	32	1	1	1	1	4	**80**	1	3	1	3	0	1	1	1	**21**
Crustacea: Cladocera	0	0	0	0	0	0	0	0	**0**	30	30	0	0	0	0	0	0	**114**
Crustacea: Copepoda	240	660	420	360	150	120	300	420	**5056**	420	120	150	360	210	30	0	480	**3352**
Crustacea: Ostracoda	210	210	571	150	210	211	91	270	**3642**	933	150	541	750	754	421	0	1292	**9168**
Arachnida: Hydracarina	90	240	90	121	150	210	121	120	**2163**	212	30	240	300	330	90	0	30	**2333**
Mollusca: Sphaerium	9	7	18	4	0	3	5	8	**102**	12	2	3	1	9	32	0	7	**125**

Mollusca: Gryaulus	0	0	0	0	0	2	1	0	**6**	1	0	0	0	0	0	0	0	**2**
Annelida: Oligochaeta	7	152	3	82	72	106	33	2	**865**	100	122	159	31	27	96	114	98	**1415**
Turbellaria	2	4	7	0	30	2	8	3	**106**	39	12	6	0	9	5	6	33	**208**
Nematoda *	60	60	60	0	120	0	0	30	**625**	0	0	0	0	0	0	0	0	**0**
Totals	1690	3123	2639	2192	1971	2226	1805	1753		3527	2079	3290	2778	3502	2063	1014	3847	

*Not included in total taxa counts or calculations for diversity.

Appendix C. Sample data for Winter Quarters Canyon (Fall 2007).

	Upper Winter Quarters Canyon								Middle Winter Quarters Canyon								Lower Winter Quarters Canyon							
Taxa	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Ephemeroptera: Baetis	881	461	462	700	347	713	423	1136	834	100	1097	992	762	948	477	672	446	478	1129	582	509	920	858	1383
Ephemeroptera: Cinygmula	254	115	138	239	272	213	274	490	99	136	402	121	647	14	173	50	105	187	445	162	568	424	229	123
Ephemeroptera: Drunella doddsi	46	1	1	1	2	15	10	4	18	10	24	59	21	3	1	0	13	1	13	2	2	3	4	9
Ephemeroptera: Drunella grandis	0	0	1	0	0	0	0	0	4	32	1	0	0	0	1	2	31	51	1	42	6	34	2	0
Ephemeroptera: Epeorus iron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0	0	0
Ephemeroptera: Ephemerella	1	8	19	5	3	1	7	4	8	1	1	2	2	2	0	4	0	0	0	0	0	0	0	0
Ephemeroptera: early instar *	8	100	3	101	67	72	39	126	269	239	335	19	101	93	68	15	123	121	0	63	349	198	226	15
Ephemeroptera:Paraleptophlebia	14	23	2	11	71	23	101	46	0	0	4	0	4	8	6	1	2	3	0	12	0	0	0	0
Ephemeroptera: Serratella tibialis	73	20	37	9	10	31	21	62	0	0	59	55	17	41	10	24	0	0	0	0	0	0	0	0
Plecoptera: early instar *	65	3	8	2	0	41	3	65	10	31	104	3	34	62	6	33	1	0	34	33	34	124	1	3
Plecoptera:Hesperoperla pacifica	2	1	1	1	2	7	1	2	7	2	66	8	6	4	2	0	8	10	1	5	1	3	1	4
Plecoptera: Isoperla	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0
Plecoptera: Paraperla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	7	0	2	0	0	0	0
Plecoptera: Pteronuarcella badia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Plecoptera: Skwalla parallela	5	2	3	3	1	3	4	2	8	2	3	4	7	0	11	10	0	0	7	2	0	0	0	0
Plecoptera: Sweltza	12	5	38	6	4	6	5	3	9	3	14	13	12	4	3	14	0	0	8	3	10	4	3	0
Plecoptera: Zapada	110	81	8	14	14	26	5	37	11	0	12	5	18	4	3	6	12	13	16	6	10	4	7	14
Trichoptera: pupae *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Trichoptera: Arctopsyche grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Trichoptera: Brachycentrus	5	0	5	10	2	2	0	3	2	0	0	2	1	63	2	0	2	2	0	1	0	0	0	6
Trichoptera: Dicosmoecus	0	0	1	5	0	0	0	0	22	5	0	33	27	0	6	17	1	0	0	1	0	0	0	17
Trichoptera: Hydropsyche	46	1	1	3	32	4	1	10	1	0	0	0	1	0	1	0	14	1	278	0	3	7	2	47
Trichoptera: Neothremma alicia	89	33	70	238	38	39	33	127	94	1	2	3	60	65	1	31	0	0	2	0	0	1	32	2
Trichoptera: Oligophlebodes	204	54	78	151	62	128	23	148	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0
Trichoptera: Parapsyche elsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	4	2	0	0	0	0
Trichoptera: Rhyacophila	36	3	5	35	3	12	0	3	5	7	15	70	81	144	114	39	3	0	34	0	3	11	10	20
Coleoptera: Heterlimnius (larvae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	1	2	0	0	1

Coleoptera: Heterlimnius (adult)	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Coleoptera: Optioservus (larvae)	453	173	496	361	217	290	224	304	212	138	230	445	225	206	442	187	136	153	251	36	284	215	90	309
Coleoptera: Optioservus (adult)	21	2	39	9	10	15	4	19	1	7	4	52	4	31	10	4	3	1	11	0	37	2	5	7
Diptera: Antocha	1	1	0	1	0	1	0	0	2	6	2	34	7	3	6	11	0	0	83	9	34	34	281	93
Diptera: Ceratopogonidae	282	152	58	282	177	136	95	323	37	11	19	144	86	74	37	29	31	41	7	37	69	17	42	6
Diptera: Chelifera	0	0	1	1	0	61	1	0	35	2	3	1	2	0	3	3	0	0	0	4	61	32	4	34
Diptera: Chironomidae (larvae)	1582	907	875	1035	464	587	612	1077	1186	655	609	697	948	1480	597	1254	525	447	1580	672	1097	897	949	1171
Diptera: Chironomidae (pupae)	0	1	0	0	1	0	0	0	39	5	3	12	9	17	10	12	32	22	6	19	11	39	2	7
Diptera: Dicranota	5	20	1	4	1	4	2	5	7	0	5	3	8	2	1	3	0	0	7	5	4	7	8	6
Diptera: Dixa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Diptera: Euparyphus	0	0	0	0	0	0	0	0	3	5	2	1	9	34	1	3	0	0	2	4	15	7	4	11
Diptera: Pericoma	448	84	356	70	83	228	90	192	409	78	113	131	121	44	85	56	29	19	38	13	78	22	33	14
Diptera: Simulium	48	42	42	34	1	66	7	44	19	83	66	23	3	170	37	7	5	0	67	0	1	11	1	1
Diptera: Tipula	8	38	6	6	5	9	8	7	0	0	0	0	1	2	1	0	50	115	0	6	4	0	1	1
Crustacea: Cladocera	0	102	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea: Copepoda	183	768	286	222	186	125	241	5	190	183	215	30	4	221	61	216	90	0	1	60	91	121	0	0
Crustacea: Ostracoda	372	425	544	798	212	157	366	222	509	216	100	148	156	98	82	534	60	32	30	64	281	216	31	6
Arachnida: Hydracarina	395	164	125	163	150	97	32	67	64	90	7	153	121	127	60	184	95	217	91	60	335	152	121	362
Mollusca: Sphaerium	122	115	391	269	194	56	174	188	3	1	5	3	31	34	3	7	13	2	1	5	6	1	32	31
Annelida: Oligochaeta	0	0	30	0	1	0	2	0	2	1	1	1	2	0	0	1	45	87	3	289	2	2	3	3
Totals	5771	3905	4131	4790	2632	3168	2810	4725	4119	2050	3523	3271	3538	3998	2321	3431	1881	2024	4159	2213	3909	3510	2982	3707

*Not included in total taxa counts or calculations for diversity.

Appendix D. Sample Data for Winter Quarters Canyon (Spring 2008).

	Upper Winter Quarters Canyon								Middle Winter Quarters Canyon								Lower Winter Quarters Canyon							
Taxa	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Ephemeroptera: Baetis	122	204	285	315	406	335	449	274	1588	777	1056	392	641	1252	581	849	218	252	422	736	216	272	1195	1253
Ephemeroptera: Cinygmula	37	52	183	262	192	371	254	259	59	91	54	92	64	57	97	81	20	89	114	147	105	221	147	354
Ephemeroptera: Drunella doddsi	2	0	1	2	4	0	1	1	0	0	2	0	10	1	3	8	0	0	1	1	0	0	0	0
Ephemeroptera: Drunella grandis	3	55	11	18	11	7	2	4	0	2	7	10	19	14	12	51	0	0	2	2	0	1	0	4
Ephemeroptera: Epeorus iron	18	64	3	37	23	0	4	39	8	10	31	15	8	2	8	3	20	12	42	34	4	82	14	60
Ephemeroptera: Ephemerella	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ephemeroptera: Heptagenia	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Ephemeroptera: Nixe criddlei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Ephemeroptera: early instar *	210	0	0	30	120	1	91	214	0	310	96	120	346	305	343	692	1920	160	1127	930	1146	1106	1798	2723
Ephemeroptera:Paraleptophlebia	0	0	0	0	0	0	0	2	2	34	33	3	4	5	10	7	0	0	1	0	0	1	1	4
Ephemeroptera: Serratella tibialis	38	68	90	122	75	88	65	111	36	38	28	27	70	24	23	54	0	0	5	43	32	38	28	46
Plecoptera: Alloperla	0	0	1	0	0	0	0	0	0	0	5	0	0	0	3	0	0	0	0	1	3	3	1	0
Plecoptera: Classenia	0	0	0	0	0	0	0	0	0	4	1	1	7	3	0	2	0	0	0	0	0	0	0	0
Plecoptera: early instar *	5	22	3	216	305	187	8	97	63	7	31	0	153	37	44	54	241	5	11	32	167	60	0	30
Plecoptera:Hesperoperla pacifica	2	0	0	0	0	0	1	0	1	1	0	2	1	0	0	4	0	3	0	0	0	0	2	1
Plecoptera: Isoperla	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Plecoptera: Malenka californica	0	0	0	0	0	0	0	0	41	11	7	33	19	14	37	38	0	0	0	0	0	0	0	0
Plecoptera: Paraperla	0	0	0	0	0	0	0	0	10	17	8	5	12	8	10	33	0	0	0	0	0	0	0	0
Plecoptera: Pteronuarcella badia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Plecoptera: Skwalla parallela	0	0	0	0	0	0	0	0	2	4	0	0	5	1	0	0	0	0	0	0	0	0	0	0
Plecoptera: Suwallia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Plecoptera: Sweltza	0	2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	33	4	11	3	2	30
Plecoptera: Zapada	3	1	0	0	0	8	32	35	7	8	8	1	24	9	8	5	0	4	4	65	55	55	11	4
Trichoptera: pupae *	0	2	1	4	0	0	2	1	1	2	3	2	3	1	2	5	3	0	2	7	0	0	0	3
Trichoptera: Arctopsyche grandis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Trichoptera: Brachycentrus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0

Trichoptera: Dicosmoecus	0	1	3	14	0	3	0	0	1	0	1	5	0	3	10	12	2	0	3	0	5	0	7	8
Trichoptera: Dolophilodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Trichoptera: Hesperophylax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Trichoptera: Hydropsyche	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera: Limniphilus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera: Neothremma alicia	6	0	2	5	3	1	5	8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera: Oligophlebodes	37	22	5	4	4	40	2	15	4	30	31	31	103	45	0	0	0	1	0	8	0	0	0	0
Trichoptera: Rhyacophila	2	0	2	5	2	3	1	3	10	10	11	8	10	6	5	9	8	1	5	5	0	9	7	10
Coleoptera: Cleptelmis	0	1	0	1	0	0	0	0	0	0	0	3	1	0	7	0	0	0	0	0	0	0	0	1
Coleoptera: Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Coleoptera: Heterlimnius (larvae)	102	172	410	419	218	249	403	260	108	471	206	76	144	122	404	217	17	12	138	74	26	147	12	27
Coleoptera: Heterlimnius (adult)	6	14	1	62	7	7	51	4	0	1	0	2	4	2	7	2	1	1	1	8	8	4	0	5
Coleoptera: Hydrobius	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Coleoptera: Micorcylleopus	1	1	0	3	0	0	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Coleoptera: Optioservus (larvae)	19	35	78	204	102	78	111	15	18	98	18	38	4	2	31	6	0	0	7	29	20	48	5	16
Coleoptera: Optioservus (adult)	0	1	0	0	2	3	1	1	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0
Diptera: Antocha	0	0	0	0	0	0	0	0	1	1	0	3	3	3	0	3	23	8	17	27	2	22	44	48
Diptera: Atherix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Diptera: Caloparyphus	0	0	0	0	0	0	0	0	0	2	0	0	0	2	2	3	2	0	0	0	5	4	0	4
Diptera: Ceratopogonidae	0	0	0	1	0	0	0	0	63	4	4	31	1	37	47	9	40	0	0	0	0	0	0	0
Diptera: Chelifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Diptera: Chironomidae (larvae)	614	24	245.	238	934	1045	604	1048	282	481	227	81	195	397	244	245	2068	265	239	154	193	546	364	628
Diptera: Chironomidae (pupae)	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	1	1	30
Diptera: *Dicranota*	3	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	34	2	0	13	1	1	4
Diptera: Euparyphus	0	1	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Diptera: Hemerodromia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Diptera: Simulium (larvae)	31	0	7	0	1	0	34	2	83	1	4	30	97	64	31	93	130	0	0	323	7	54	2094	129
Diptera: Simulium (pupae)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	94	2
Diptera: Tipula	0	0	0	2	0	0	1	0	0	0	1	0	0	0	0	1	0	3	0	1	0	0	0	0

Crustacea: Cladocera	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea: Copepoda	210	0	90	360	90	211	361	362	30	150	180	120	120	150	240	60	0	0	60	0	0	0	0	0
Crustacea: Ostracoda	10	0	720	630	180	303	151	330	30	302	60	271	240	153	363	510	40	36	126	33	117	91	39	150
Arachnida: Hydracarina	120	20	122	360	91	216	180	184	90	91	60	60	63	120	182	60	80	122	34	213	8	150	61	210
Mollusca: Sphaerium	9	0	120	73	43	96	80	19	2	18	14	14	10	19	10	10	0	0	0	0	0	0	0	0
Mollusca: Gyraulus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Mollusca: Lymai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Annelida: Oligochaeta	55	140	160	49	79	124	129	60	21	96	29	78	91	85	64	48	24	195	35	66	523	30	44	14
Collembola	2	0	31	0	0	1	1	5	0	30	31	0	0	0	1	30	0	0	0	0	0	0	1	0
Lepidoptera	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Turbellaria	54	91	99	89	48	83	69	158	1	0	6	4	14	10	0	1	0	0	1	4	14	30	3	5
Nematoda	0	40	61	120	0	4	150	90	0	61	0	90	0	30	31	60	40	0	0	0	30	60	0	0
Totals	1721	1034	2736	3646	2948	3470	3246	3602	2565	3164	2285	1648	2490	2984	2861	3269	4902	1211	2433	2954	2711	3040	5984	5808

* Not included in total taxa counts or calculations for diversity.

AN ASSESSMENT OF THE MACROINVERTEBRATES of Eccles Creek

in

September 2007 and July 2008

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INTRODUCTION

In August, 2001, an aquifer tapped by Skyline Mine, near Scofield, UT, significantly increased the discharge of water from the mine into Eccles Creek. The discharge maintained the stream at approximately bank-full levels. This report summarizes results of monitoring of the benthic invertebrate community in Eccles Creek through the summer of 2008. It includes summaries of previous data to maintain the context for comparative purposes and a multivariate analysis of all available benthic data for Eccles Creek collected through 2008. The samples taken in summer, 2008, represent the ninth series taken from the stream following the increased discharge. This project was undertaken for Canyon Fuel Company with the objective of determining the impact of the increased flows on the stream community.

METHODS

Quantitative samples were taken from Eccles Creek in September 2007 and July 2008. The three stations sampled were Eccles Creek above South Fork (EC2: N 39^0 40.970', W 111.11.579', 8,406 feet elevation), Eccles Creek at Whisky Canyon (EC-4: N 39^0 40.908', W 111.10.747', 8,234 feet elevation), and Lower Eccles Creek (EC-5: N 39^0 41.001', W 111.10.031', 8,074 feet elevation). These three stations have been sampled intermittently since 1979 (Shiozawa 2003). The samples were taken from the same locations sampled in July and October, 2002; June and October, 2003; and October and June 2004. Five replicate samples were taken per station. All samples were taken from locations in the stream where rubble or cobble substrates were present. A box sampler with a net mesh of 250 microns was used to collect the samples. The substrate was stirred to a depth of approximately 5 cm whenever possible. In some cases, the streambed could only be brushed. All rocks within the area of the sampler were removed and individually washed to insure quantitative collection of the invertebrates. The samples were concentrated on a screen with a mesh of 64 microns and field preserved in ethyl alcohol. A GPS unit was used to locate the sample stations.

In the laboratory, the samples were sorted in illuminated pans. All invertebrates were removed and identified to the lowest possible taxonomic level using the keys of Merritt and Cummins (1996) and Merritt et al. (2008). The visually sorted samples were then subsampled by suspending the residual sample in a volume of 200 ml of water. Five 2 ml subsamples were removed and processed under magnification with a dissecting scope. The mean density per subsample was used to project the total density of organisms remaining in the sample. These projections were added to the total count from the visual sorting. The data were then used to determine the density of taxa per square meter. Mean biomass estimates, based on wet weights of invertebrates, were also generated so that trends in standing crop could be documented.

Analyses included comparisons of the number of taxa and mean densities in the July 2008 , samples with those generated from samples taken September 2007; October, 2004 (Shiozawa 2007); June 2004 (Shiozawa and Kauwe 2006); October, 2003; June 2003; October, 2002; November, 2001 (Shiozawa 2002a); and July, 2002 (Shiozawa 2002c) and with samples taken in 1979 (Winget 1980) and 1992 (Ecosystems Research Institute 1992). These comparisons allow a general evaluation of changes that have occurred since the increased discharge of water into the stream channel from the mine and help place the results in perspective relative to other perturbations as well as baseline conditions.

The community tolerance quotient (CTQ; Winget and Mangum 1979) was used to gain insight into the condition of the stream relative to that predicted for an idealized system from slope, water chemistry, and substrate. Water chemistry for Eccles Creek was provided by EarthFax Engineering (2001). The following estimates were used for alkalinity and sulfate levels: Eccles Creek alkalinity recorded levels at 264 mg/l and sulfate estimated at 49 mg/l. The gradient in Eccles Creek is approximately 3.3%. With its combination of physical properties, it had a predicted community tolerance quotient (CTQp) of 80 (Winget and Mangum 1979). The Biotic Condition Index was used to further interpret the data generated with this procedure.

Diversity was calculated for the stations using the Shannon-Weiner index (Pieliou 1977). This allows a general comparison among sample stations and dates. Diversity indices take the number of taxa and their individual densities into account, generating a single value for each station. The greater the number of species or taxa and generally the more even the distribution of densities among taxa, the higher the diversity index value.

The data were clustered with the UPGMA algorithm using the Bray-Curtis measure of dissimilarity (Poole 1974, Krebs 1989). The NTSYSpc package was utilized to generate the cluster dendrograms (Rolf 2000). As a final analysis, the entire data set was examined with an ordination technique, correspondence analysis (Braak and Smilauer 2002). This was accomplished with the full data set. A log X+1 transformation was applied to the data to reduce the effect of high densities. This procedure is used mainly as an exploratory method so that general trends in the sampling stations can be graphically appraised.

RESULTS AND DISCUSSION

Number of Taxa

Twenty-seven taxa were collected from Eccles Creek in the fall of 2007 while twenty-two taxa were collected in the summer 2008. The highest number of taxa were collected at station EC4 both sampling periods. The total number of taxa is the highest collected from Eccles Creek since the recent sampling series began in 2001. Excluding two categories (unidentified plecopterans and chironomid pupae), seven taxa were collected in station EC2, 24 taxa in station EC4 and 17 in station EC5 in the fall 2007 series (Table 1). The summer 2008 samples series had 7 taxa in station EC2, 15 taxa in station EC4 and 11 in station EC5. As seen in previous sampling efforts, higher numbers of taxa tend to be collected in the fall samples. The upper station, EC2, has not shown any pattern of increased taxa through the sample period. This station has the greatest amount of carbonate precipitation on the substrate and that factor likely limits all but epibenthic invertebrates. The other two stations have greater numbers of taxa than were collected in the early 2002 samples, but do not seem to be increasing in total taxa much beyond the 2004 sample series.

Table 1. Number of taxa collected from Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	Shiozawa & Hansen 2004	Shiozawa 2005	Shiozawa 2005	Shiozawa 2007	This report	This report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003	Oct 2003	June 2004	Oct 2004	Sept 2007	July 2008
South Fork tributary above mine, upper site (USF2)			20	11										
South Fork tributary above mine (USF)	30		12	9	21									
Middle Fork tributary above mine (UMF)	29		14	18										
Eccles Creek below mine (EC1)			4	2										
Eccles Creek above south Fork (EC2)	35	42	6		6		6	11	11	5	10	7	7	7
South Fork Eccles Creek (SF)	36	35	12											
Eccles Creek below South Fork (EC3)	27	30												
Eccles Creek at Whisky Canyon (EC4)	35	37	7	17	15	6	14	7	9	13	14	16	24	15
Lower Eccles Creek (EC5)	38	21	12	13/11	14		6	11	9	11	21	24	17	11

All stations are below the baseline number of taxa collected in 1979. In 2004, station EC5 could have been considered to have recovered to pre-mining conditions based on the total taxa count alone, but in both 2007 and 2008 the number of taxa had again decreased. The taxa count for the other two stations, EC2 and EC4, were below the base-line counts of 1979 for their respective locations. Total taxa counts give one measure of the state of the community but, by themselves, such counts are relatively uninformative except for giving a rough estimate of diversity.

Total Density Comparisons

In September 2007 the total density estimates in stations EC2 and EC4 were lower than they had been in 2002, the first series of samples following the increased discharge into Eccles Creek. The total density in station EC5 was several times higher than the 2002 estimates. The total densities (Table 2) of invertebrates in all three stations in 2008 were considerably higher than the densities recorded in 2002. Station EC2, the upstream most station, had the highest total density recorded since the increase in discharge, and was actually higher than the May-June estimates in 1979. The lower two stations' 2008 total densities were also in the range of the 1979 sample series. While the 2007 samples in EC2 and EC4 were indicative of no change, the 2008 data suggests that the system may have recovered in total numbers, despite the contrasting evidence from the number of taxa discussed above. Yet despite these total densities being within the range of 1979, both EC4 and EC5 2008 densities have decreased to one fifth to one eighth of the 2004 density estimates at those same stations (Table 2).

The extreme increases in Eccles Creek station densities in October 2004 were at stations EC4 and EC5. This was partly due to seasonal changes in community structure. Early instars of many invertebrates can pass through a 250 micron mesh net, and chironomids often overwinter in early instars (e.g. Shiozawa and Barnes 1977). By June they would have grown to a size that could be more readily collected by the benthic sampler. In addition, our protocol of sorting samples under dissecting scopes after general sorting is much more accurate than open-pan sorting. While we do not know how the processing was completed in the previous studies, we do know that our approach will give a more accurate count of individuals when compared to open-pan sorting alone. A third factor that may have had an impact was the failure of several beaver dams above these sites. These released significant amounts of sediment into the stream channel and the increased sediment would be favorable to the benthic invertebrates.

Based on total densities, both EC4 and EC5 in 2008 were near pre-impact numbers. If density alone were a function of recovery, and if higher numbers denote greater recovery, then those two stations could be considered to have recovered. However, that would also imply that the October 2004 density estimates indicated that the stations had exceeded the baseline conditions. As noted previously (Shiozawa 2007), in stressed systems a few taxa often dominate the community with high numbers of individuals and these can easily mask the state of the community.

Table 2. Total invertebrate densities per square meter for selected studies on Eccles Creek

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	Shiozawa & Hansen 2004	Shiozawa 2005	Shiozawa 2005	Shiozawa 2007	Shiozawa 2009	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003	Oct 2003	June 2004	Oct 2004	Sep 2007	Jul 2008
South Fork tributary above mine, upper site (USF2)			1,089	528										
South Fork tributary above mine (USF)	10,179		1,144	216	2,455									
Middle Fork tributary above mine (UMF)	7,447		1,503	3,812										
Eccles Creek below mine (EC1)			164	16										
Eccles Creek above South Fork (EC2)	12,341	73,181	267		89		3,703	1,260	6,265	1,267	10,865	4,339	2,436	15,772
South Fork Eccles Creek (SF)	9,321	17,773	1,356											
Eccles Creek below South Fork (EC3)	18,093	23,247												
Eccles Creek at Whisky Canyon (EC4)	11,634	25,273	1,719	3,928	1 419	61	8,757	1,491	10,351	5,004	73,950	38,093	6,332	13,926
Lower Eccles Creek (EC5)	18,661	2,526	2,212	4,104/ 2,863	1,468		4,927	2,879	3,387	16,919	97,614	65,206	10,878	12,743

Taxa Specific Densities

While total densities can give a quick picture of the state of the stream system, they can also be misleading if the component taxa are not considered. High densities of relatively few taxa are common in stressed or polluted systems because a few tolerant taxa are able to monopolize resources. This is especially enhanced in an environment with reduced predation and competition.

Baetis were absent or rare in the June 2003 sampling series. In the July 2002 samples (Shiozawa 2002c), *Baetis* densities were moderate at 242/m^2, 491/m^2, and 200/m^2 in EC2, EC4, and EC5 respectively. The October 2002 samples showed *Baetis* absent at EC2, about the same density at EC4 (400/m^2) and higher at EC5 (1,297/m^2). Yet in the June 2003 samples, only six *Baetis* per square meter were found at EC4, and none were present at EC2 or EC5. However, by the following sample period, the fall, 2003, *Baetis* density had rebounded in stations EC4 and EC5 with 2448/m^2 and 13,835/m^2. None were collected in station EC2. By spring, 2004, *Baetis* was again collected at station EC2 where a density of 1,151/m^2 was recorded. During that same sampling period, station EC4 had *Baetis* densities of 2,362/m^2, almost identical with the previous fall, and the downstream station EC5 had a density estimate of 8,302/m^2, a third less than recorded in the previous fall samples. In fall, 2004, *Baetis* density at station EC2 was estimated at 1,151/m^2 (Table 3), identical with the estimate for spring, 2004. While the mean density estimate is identical for the two seasons, the densities per sample were not. The spring samples showed a more clumped distribution than the fall samples. In fall, 2004, both of the lower stations had a significant increase in *Baetis*. Station EC4 had 18,392/m^2, and EC5, had 44,341/m^2. The decrease of *Baetis* in 2003 was interpreted as being a transient perturbation although the failure of *Baetis* to increase at station EC2 was thought to be associated with the scouring and armoring of the streambed. In September 2007 *Baetis* densities were 127/m^2 in both EC2 and EC5 and 370/m^2 in EC4 (Table 3). In July 2008 their numbers were18/m^2 in EC2, 473/m^2 in EC4 and 73/m^2 in EC5 (Table 4). These recent data indicate that the high 2003-2004 densities may have been transient, and the 2003 densities were more indicative of prevailing conditions.

The mayfly, *Cinygmula,* was in low densities in the 2007-2008 samples, only being collected in station EC5 (5/m^2 and 6/m^2 in 2007 and 2008; Tables 3 and 4). It was not collected in the fall 2004 sample series. In spring, 2003, it was in moderate densities in the upstream site (EC2*)* with a density of 230/m^2 but rare or absent in the middle (EC4) and lower (EC5) sites. This genus was also absent in the fall, 2002, samples but was in very low densities at stations EC2 and EC4 in July 2002, and was in moderate densities (182/m^2) in station EC4 in fall, 2003. In spring, 2004, it was only found at station EC2 in low density (12/m^2). *Cinygmula* is characteristic of relatively high quality systems. It is a scraper-gatherer feeding on algae and detritus on the surface of rocks. Prior to the construction of the road, this genus reached densities of over 8,000 per square meter in late summer, although spring and early summer densities were around 1,000 per square meter in the middle and upper reaches of Eccles Creek (Shiozawa 2002b). The lack of this taxon indicates that it has not adapted to the changes induced by or accompanying the increased flow even though it utilizes rock surfaces for feeding and the entire streambed in station EC2 should be available for its use.

Table 3. September, 2007, sample data and invertebrates per square meter.

	Eccles Creek above South Fork (EC2)						Eccles Creek Whisky Canyon (EC4)					
Taxa	1	2	3	4	5	**#/m²**	1	2	3	4	5	**#/m²**
Ephemeroptera: *Baetis*	1	7	7	5	1	**127**	2	5	26	4	24	**370**
Ephemeropter: *Cinygmula*	0	0	0	0	0	**0**	0	0	0	1	0	**6**
Ephemeroptera: early instar*	53	9	17	10	9	**594**	0	3	36	4	150	**1170**
Plecoptera: early instar*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Plecoptera: *Paraperla frontalis*						**0**	0	0	1	0	0	**6**
Plecoptera: *Malenka californica*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: early instar*	0	0	0	0	0	**0**	0	0	16	0	2	**109**
Trichoptera: *Brachycentrus*	0	0	0	0	0	**0**	0	0	0	0	4	**24**
Trichoptera: *Hesperophylax*						**0**	3	1	0	0	0	**24**
Trichoptera: *Hydropsyche*	0	0	0	0	0	**0**	0	25	21	3	59	**654**
Trichoptera: *Hydroptila*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: Ochrotrichia	0	0	0	0	0	**12**	0	0	2	0	0	**12**
Trichoptera: *Polycentropus*	0	0	0	0	0	**0**	0	0	1	0	0	**6**
Trichoptera: *Rhycophila*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: pupae*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: Dytiscidae	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (adult)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (larvae)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (adult)	0	0	0	0	0	**0**	0	0	1	0	0	**6**
Coleoptera: *Optioservus* (larvae)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Antocha*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: Caloparyphus	0	0	0	0	0	**0**	1	0	2	1	0	**24**
Diptera: Ceratopogonidae	0	0	1	0	1	**12**	0	0	1	0	1	**12**

Diptera: Chironomidae larva	12	2	66	39	13	**800**	125	15	86	15	112	**2139**
Diptera: Chironomidae pupae	1	1	1	0	0	**18**	0	0	2	0	3	**30**
Diptera: *Chelifera*	11	0	0	4	0	**91**	0	0	1	0	1	**12**
Diptera: *Dicranota*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Euparyphus*	0	0	0	0	0	**0**	0	0	2	0	0	**12**
Diptera: *Limnophora*	0	0	0	1	0	**6**	0	0	0	0	0	**0**
Diptera: *Limnophila*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Hemerodromia*	0	0	0	0	0	**0**	1	0	1	12	3	**103**
Diptera: Neoplasta	0	0	0	0	0	**0**	0	0	0	0	11	**67**
Diptera: *Rhabdomastix*	0	0	0	0	0	**0**	2	0	0	0	0	**12**
Diptera: Phoridae	0	0	0	0	0	**0**	0	0	0	0	1	**6**
Diptera: *Simulium*	0	0	0	0	0	**0**	0	0	0	0	1	**6**
Diptera: *Tipula*	0	0	0	0	1	**6**	3	0	0	0	0	**18**
Crustacea: Copepoda	0	0	0	0	0	**0**	0	0	21	1	1	**139**
Crustacea: Ostracoda	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Arachnida: Hydracarina	0	0	0	0	0	**0**	·13	11	2	11	0	**224**
Mollusca: *Gyrulus*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Mollusca: *Sphaerium*	0	0	0	0	0	**0**	11	12	2	10	3	**230**
Annelida: Oligochaeta	49	12	41	5	22	**782**	80	47	118	0	104	**2115**
Nematoda	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Totals:	127	31	133	64	47	**2448**	241	119	342	62	480	**7536**

Table 3 (cont.). September, 2007, sample data and invertebrates per square meter.

	Lower Eccles Creek (EC5)					
Taxa	1	2	3	4	5	**#/m²**
Ephemeroptera: *Baetis*	1	7	7	5	1	**127**
Ephemeropter: *Cinygmula*	0	0	0	0	0	**0**
Ephemeroptera: early instar*	53	9	17	10	9	**594**
Plecoptera: early instar*	0	0	0	0	0	**0**
Plecoptera: *Paraperla frontalis*	0	0	0	0	0	**0**
Plecoptera: *Malenka californica*	0	0	0	0	0	**0**
Trichoptera: early instar*	0	0	0	0	0	**0**
Trichoptera: *Brachycentrus*	0	0	0	0	0	**0**
Trichoptera: *Hesperophylax*	0	0	0	0	0	**0**
Trichoptera: *Hydropsyche*	0	0	0	0	0	**0**
Trichoptera: *Hydroptila*	0	0	0	0	0	**0**
Trichoptera: Ochrotrichia	0	0	0	0	0	**0**
Trichoptera: *Polycentropus*	0	0	0	0	0	**0**
Trichoptera: *Rhycophila*	0	0	0	0	0	**0**
Trichoptera: pupae*	0	0	0	0	0	**0**
Coleoptera: Dytiscidae	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (adult)	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (larvae)	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (adult)	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (larvae)	0	0	0	0	0	**0**
Diptera: *Antocha*	0	0	0	0	0	**0**
Diptera: Caloparyphus	0	0	0	0	0	**0**
Diptera: Ceratopogonidae	0	0	1	0	1	**12**

Diptera: Chironomidae larva	12	2	66	39	13	**800**
Diptera: Chironomidae pupae	1	1	1	0	0	**18**
Diptera: *Chelifera*	11	0	0	4	0	**91**
Diptera: *Dicranota*	0	0	0	0	0	**0**
Diptera: *Euparyphus*	0	0	0	0	0	**0**
Diptera: *Limnophora*	0	0	0	1	0	**6**
Diptera: *Limnophila*	0	0	0	0	0	**0**
Diptera: *Hemerodromia*	0	0	0	0	0	**0**
Diptera: Neoplasta	0	0	0	0	0	**0**
Diptera: *Rhabdomastix*	0	0	0	0	0	**0**
Diptera: Phoridae	0	0	0	0	0	**0**
Diptera: *Simulium*	0	0	0	0	0	**0**
Diptera: *Tipula*	0	0	0	0	1	**6**
Crustacea: Copepoda	0	0	0	0	0	**0**
Crustacea: Ostracoda	0	0	0	0	0	**0**
Arachnida: Hydracarina	0	0	0	0	0	**0**
Mollusca: *Gyrulus*	0	0	0	0	0	**0**
Mollusca: *Sphaerium*	0	0	0	0	0	**0**
Annelida: Oligochaeta	49	12	41	5	22	**782**
Nematoda	0	0	0	0	0	**0**
Totals:	**127**	**31**	**133**	**64**	**47**	**2436**

Table 4. July, 2008, sample data and invertebrates per square meter.

	Eccles Creek above South Fork (EC2)						Eccles Creek Whisky Canyon (EC4)					
Taxa	1	2	3	4	5	**#/m2**	1	2	3	4	5	**#/m2**
Ephemeroptera: *Baetis*	0	0	0	0	3	**18**	5	3	3	7	60	**473**
Ephemeropter: *Cinygmula*	0	0	0	0	1	**6**	0	0	0	0	0	**0**
Ephemeropter: *Drunalla doddsi*	**0**	**0**	**35**	**0**	**0**	**212**	**0**	**0**	**0**	**0**	**0**	**0**
Ephemeroptera: early instar*	0	1	3	1	0	**30**	0	0	0	0	10	**61**
Plecoptera: early instar*	0	0	0	0	2	**12**	0	0	0	0	0	**0**
Plecoptera: *Paraperla frontalis*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Plecoptera: *Malenka californica*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Plecoptera: *Skwalla parallela*	0	0	0	0	0	**0**	1	0	0	0	0	**6**
Trichoptera: early instar*	0	0	0	0	0	**0**	10	20	20	0	0	**303**
Trichoptera: *Brachycentrus*	0	0	0	0	0	**0**	0	0	0	0	10	**61**
Trichoptera: *Hesperophylax*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: *Hydropsyche*	0	0	0	0	0	**0**	0	0	2	0	0	**12**
Trichoptera: *Hydroptila*	0	0	36	0	36	**448**	1	12	2	3	0	**109**
Trichoptera: Ochrotrichia	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: *Polycentropus*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Trichoptera: *Rhycophila*	2	0	35	0	0	**224**	0	0	2	2	0	**24**
Trichoptera: pupae*	0	0	0	0	0	**0**	0	0	0	1	0	**6**
Coleoptera: Dytiscidae	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (adult)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (larvae)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (adult)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (larvae)	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Antocha*	0	0	0	0	0	**0**	0	0	0	0	0	**0**

Diptera: Caloparyphus	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: Ceratopogonidae	0	0	0	0	0	**0**	0	0	0	0	1	**6**
Diptera: Chironomidae larva	1050	235	151	116	103	**10029**	196	148	185	278	357	**7054**
Diptera: Chironomidae pupae	43	5	3	1	2	**327**	5	12	6	20	34	**467**
Diptera: *Chelifera*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Dicranota*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Dixa*	0	0	0	0	0	**0**	0	0	1	0	0	**6**
Diptera: *Euparyphus*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Limnophora*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Limnophila*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Hemerodromia*	0	0	0	0	0	**0**	0	1	0	1	0	**12**
Diptera: Neoplasta	0	0	0	0	0	**0**	1	1	2	2	2	**48**
Diptera: *Rhabdomastix*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: Phoridae	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Ptychoptera*	0	0	0	0	0	**0**	1	0	0	0	0	**6**
Diptera: *Scatella*	0	0	0	0	0	**0**	0	0	1	0	0	**6**
Diptera: *Simulium*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Diptera: *Tipula*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Crustacea: Copepoda	0	0	0	0	0	**0**	30	10	0	21	0	**370**
Crustacea: Ostracoda	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Arachnida: Hydracarina	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Mollusca: *Gyrulus*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Mollusca: *Sphaerium*	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Annelida: Oligochaeta	76	280	182	20	179	**4466**	145	201	103	164	195	**4896**
Nematoda	0	0	0	0	0	**0**	0	0	0	0	0	**0**
Totals:	**1171**	**521**	**445**	**138**	**326**	**15772**	395	408	327	499	669	**13926**

Table 4 cont. July, 2008, sample data and invertebrates per square meter.

	Lower Eccles Creek (EC5)					
Taxa	1	2	3	4	5	**#/m2**
Ephemeroptera: *Baetis*	0	1	6	0	5	**73**
Ephemeropter: *Cinygmula*	0	0	0	0	0	**0**
Ephemeropter: *Drunalla doddsi*	**0**	**0**	**0**	**0**	**0**	**0**
Ephemeroptera: early instar*	0	0	1	0	1	**12**
Plecoptera: early instar*	0	0	0	0	0	**0**
Plecoptera: *Paraperla frontalis*	0	0	0	0	0	**0**
Plecoptera: *Malenka californica*	0	0	0	0	0	**0**
Plecoptera: *Skwalla parallela*	0	1	0	0	3	**24**
Trichoptera: early instar*	0	0	0	0	0	**0**
Trichoptera: *Brachycentrus*	0	0	0	0	0	**0**
Trichoptera: *Hesperophylax*	0	0	0	0	0	**0**
Trichoptera: *Hydropsyche*	0	0	0	0	1	**6**
Trichoptera: *Hydroptila*	31	0	1	0	0	**194**
Trichoptera: Ochrotrichia	0	0	0	0	0	**0**
Trichoptera: *Polycentropus*	0	0	0	0	0	**0**
Trichoptera: *Rhycophila*	0	0	0	0	2	**12**
Trichoptera: pupae*	0	0	0	0	0	**0**
Coleoptera: Dytiscidae	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (adult)	0	0	0	0	0	**0**
Coleoptera: *Heterlimnius* (larvae)	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (adult)	0	0	0	0	0	**0**
Coleoptera: *Optioservus* (larvae)	0	0	0	0	0	**0**
Diptera: *Antocha*	0	0	0	0	0	**0**

Diptera: Caloparyphus	0	0	0	0	0	**0**
Diptera: Ceratopogonidae	0	0	0	0	0	**0**
Diptera: Chironomidae larva	160	96	232	183	120	**4793**
Diptera: Chironomidae pupae	0	1	0	0	0	**6**
Diptera: *Chelifera*	0	0	0	0	0	**0**
Diptera: *Dicranota*	0	0	0	0	0	**0**
Diptera: *Dixa*	0	0	0	0	0	**0**
Diptera: *Euparyphus*	0	0	0	0	0	**0**
Diptera: *Limnophora*	0	0	0	0	0	**0**
Diptera: *Limnophila*	0	0	0	0	0	**0**
Diptera: *Hemerodromia*	0	0	0	0	0	**0**
Diptera: Neoplasta	3	0	4	0	1	**48**
Diptera: *Rhabdomastix*	0	0	0	0	0	**0**
Diptera: Phoridae	0	0	0	0	0	**0**
Diptera: *Ptychoptera*	0	1	0	0	0	**6**
Diptera: *Scatella*	0	0	0	0	0	**0**
Diptera: *Simulium*	0	0	0	0	0	**0**
Diptera: *Tipula*	0	0	0	0	0	**0**
Crustacea: Copepoda	30	0	0	0	30	**364**
Crustacea: Ostracoda	30	0	30	30	60	**909**
Arachnida: Hydracarina	0	0	0	0	0	**0**
Mollusca: *Gyrulus*	0	0	0	0	0	**0**
Mollusca: *Sphaerium*	0	0	0	0	0	**0**
Annelida: Oligochaeta	91	374	155	233	186	**6296**
Nematoda	0	0	0	0	0	**0**
Totals:	**345**	**474**	**429**	**446**	**409**	**12743**

The hydroptilid caddisfly, *Ochrotricha* (a micro-caddisfly), was absent in the fall, 2004, samples, yet at station EC5 in spring, 2004, its density was 5,830/m^2, and at station EC4, it was collected at 1,327/m^2. In 2007 this genus was collected at 12/m^2 in station EC4, but it was absent in the other two stations. In 2008 no *Ochrotricha* were collected. *Hydroptilla* were collected at 55/m^2 from station EC5 in fall, 2004 but none were collected in September of 2007. In July 2008 this taxon reappeared in densities of 448/m^2, 109/m^2, and 194/m^2 respectively in station EC2, EC4, and EC5. These insects attach to the surface of rocks and woody debris and feed on algae growing on the surface of the substrate. It appears that *Hydroptilla* may be better adapted than *Ochrotricha* to the conditions existing in Eccles Creek.

In the fall of 2004, *Hydropsyche* was absent at station EC2 but occurred at stations EC4 and EC5 at densities of 897/m^2 and 212/m^2 respectively. This is in contrast with 73/m^2 and 199/m^2 at those two stations in spring, 2004. In the previous fall samples (2003), *Hydropsyche* was collected at 394/m^2, 1,245/m^2, and 242/m^2 from stations EC2, EC4, and EC5 respectively. *Hydropsyche*, like *Baetis*, was not collected in the spring, 2003, sample series but had been the dominant benthic macroinvertebrate in the October 2002 samples (1,030/m^2, 1,024/m^2, 1,321/m^2 at stations EC2, EC4, and EC5 respectively). This suggests that the loss of hydropsychids in spring, 2003, was a result of an unknown perturbation that affected the stream in the winter/spring of 2003. The fall, 2004, numbers are little changed from the fall, 2003, densities at stations EC4 and EC5, but *Hydropsyche* was not collected from station EC2 during the spring and fall sampling periods in 2004. In September 2007 *Hydropsyche* was absent from Station EC2, but it occurred in densities of 654/m^2 and 442/m^2 in stations EC4 and EC5 respectively. In July 2008 *Hydropsyche* again was absent in Station EC2, and it was much reduced in stations EC4 and EC5 (12/m^2 and 6/m^2; Table 4). The absence of individuals of this genus at station EC2 in 2004, 2007, and 2008, while it was present in the fall, 2003, implies that changes in the environment at that station may have reduced recruitment onto the substrate. It also appears that numbers are decreasing significantly in stations EC4 and EC5.

Chironomids, in September 2007 were in densities of 800/m^2, 2139/m^2, and 1109/m^2 in stations EC2, EC4, and EC5 respectively. In July of 2008 their numbers increased to 10029/m^2, 7054/m^2, and 4793/m^2 in those same three stations. In October 2004, chironomids numbered 200/m^2, 2,769/m^2, and 5,363/m^2 in stations EC2, EC4, and EC5 respectively. In the previous October samples (2003), they numbered 479/m^2, 642/m^2, and 1,036/m^2 at the same three stations. The October 2004 density was down in station EC2 but was up in both of the lower stations. In contrast, the June 2004 density estimates of 6,060/m^2, 18,265/m^2, and 33,451/m^2 included the highest numbers recorded in the EC4 and EC5 sample series. This supports a seasonal fluctuation in numbers of midges within the system, but seasonality does not fully explain the high densities in the spring of 2004.

Oligochaetes also show a seasonal abundance signal. In June 2002 they numbered 79/m^2, 654/m^2, and 576/m^2 in stations EC2, EC4, and EC5 respectively. In fall, 2002, the numbers fell to 79/m^2, 0/m^2, and 0/m^2 at the same three sites. The following year, in the spring of 2003, the density estimates were 442/m^2, 879/m^2, and 103/m^2, slightly higher at stations EC2 and EC4 than the previous spring. But again in October 2003 the densities at stations EC2 and EC4 had declined to 24/m^2 and 24/m^2. Station EC5, however, increased to 1,079/m^2. By spring, 2004, the densities of oligochaetes in all stations increased, especially in the two downstream stations. Their spring, 2004, densities were $2,939/m^2$, $48,965/m^2$, and $37,378/m^2$ in EC2, EC4, and EC5 respectively. By October 2004 the numbers had declined at stations EC4 and EC5 to $14,247/m^2$ and $8,514/m^2$ respectively. Station EC2, with $2,782/m^2$, was only slightly lower than the spring, 2004, estimates. The September 2007 oligochaete densities were $782/m^2$, $2114/m^2$, and $1279/m^2$, again reflecting a fall decrease in density. By July 2008 the numbers had again increased to $4466/m^2$, $4896/m^2$, and $6296/m^2$. However the 2008 densities were significantly lower in stations EC4 and EC 5 than were recorded in 2004. Oligochaetes are deposit feeders burrowing into sand depositional microhabitats. Their increasing abundance in 2004 may have reflected both an increase in sand habitat (at the expense of silt habitats) as several beaver dams washed out in the stream system. If that was the case, then future studies, barring additional sand input from upstream beaver dams, may find a continuing decline in oligochaete densities as the fine sediments are flushed from the system.

Biomass

Total biomass estimates were generated for each station and for both sampling periods (Table 5). These biomass estimates can be compared with the biomass estimates from previous collections (Table 6) to gain insight into the standing stock of energy in the system at different time periods. We do not have biomass estimates for Eccles Creek prior to the increased discharge in 2001, but we can use biomass estimates from Woods and Winter Quarters canyons (Shiozawa 2004, Shiozawa and Fordham 2010; Table 7) for comparison since those two streams parallel Eccles Creek and should be similar to the pre-impact Eccles Creek system.

The overall mean biomass for Woods and Winter Quarters canyons is just over 43 g/m^2. In contrast, Eccles Creek mean biomass is 9 g/m^2. The biomass estimates in Woods-Winter Quarters range from 17.6 g/m^2 to 86.6 g/m^2 while the range in Eccles Creek is from 1.82 g/m^2 to 36.7 g/m^2. The high estimate for Eccles Creek came from EC4 in June of 2004 and is double the biomass of the next highest estimate, which is from the 2000-08 series from Eccles Creek. Both the September 2007 and July 2008 overall biomass estimates for Eccles Creek are a fifth to a seventh of the respective Woods-Winter Quarters estimates. In addition, the upper station, EC2, in Eccles Creek is almost always the lowest in biomass of the three sites on that stream. In September of 2007 its biomass was just 7% of that in the Woods and Winter Quarters samples and in July of 2008 the EC2 biomass was about 13% of the Woods-Winter Quarters mean.

Table 5. Biomass estimates, September 2007 and July, 2008.

	Upper Eccles (EC2)		Middle Eccles (EC4)		Lower Eccles (EC5)	
Sample	Sep-07	Jul-08	Sep-07	Jul-08	Sep-07	Jul-08
1	0.070 g	0.28 g	0.32 g	0.23 g	0.05 g	0.15 g
2	0.021 g	0.24 g	0.13 g	0.17 g	0.04 g	0.11 g
3	0.002 g	0.16 g	0.45 g	0.17 g	0.47 g	0.22 g
4	0.200 g	0.09 g	0.04 g	0.31 g	0.51 g	0.17 g
5	0.007 g	0.17 g	0.52 g	0.27 g	0.20 g	0.24 g
total	0.30 g	0.95 g	1.44 g	1.14 g	0.87 g	0.88 g
g/m^2	1.82 g/m^2	5.73 g/m^2	8.75 g/m^2	6.91 g/m^2	5.25 g/m^2	5.33 g/m^2

Table 6. Biomass averages for Eccles Creek 2002-2008.

	October 2002	June 2003	June 2004	October 2004	September 2007	July 2008	Average
Upper Eccles (EC2)	16.06 g/m^2	6.46 g/m^2	3.21 g/m^2	2.36 g/m^2	1.82 g/m^2	5.73 g/m^2	5.94 g/m^2
Middle Eccles (EC4)	10.40 g/m^2	6.67 g/m^2	36.66 g/m^2	10.75 g/m^2	8.75 g/m^2	6.91 g/m^2	13.36 g/m^2
Lower Eccles (EC5)	11.92 g/m^2	3.74 g/m^2	16.28 g/m^2	19.68 g/m^2	5.25 g/m^2	5.33 g/m^2	10.37 g/m^2
Average	12.79 g/m^2	5.62 g/m^2	18.72 g/m^2	6.12 g/m^2	5.27 g/m^2	5.99 g/m^2	**9.08 g/m^2**

Table 7. Biomass in g/m^2 for Woods and Winter Quarter Canyons based on Shiozawa (2004) and Shiozawa and Fordham (2010).

	Jun-03	Oct-03	Jun-04	Sep-07	Jul-08	Average
Upper Woods Canyon	36.57 g/m^2	31.64 g/m^2	30.78 g/m^2	32.98 g/m2	35.49 g/m2	33.49
Lower Woods Canyon	54.58 g/m^2	49.43 g/m2	57.19 g/m^2	22.52 g/m2	31.45 g/m2	43.03
Upper Winter Quarters Canyon	39.77 g/m^2	51.82 g/m^2	47.07 g/m^2	17.56 g/m2	42.03 g/m2	39.65
Middle Winter Quarters Canyon	37.62 g/m^2	67.18 g/m^2	52.43 g/m^2	22.75 g/m2	67.06 g/m2	49.41
Lower Winter Quarters Canyon	57.23 g/m^2	37.72 g/m^2	86.60 g/m^2	30.88 g/m2	42.31 g/m2	50.95
Average	45.15 g/m^2	47.56 g/m^2	54.81 g/m^2	25.34 g/m^2	43.67 g/m^2	**43.31 g/m^2**

This reinforces the scenario developed in earlier reports where we felt that the armoring of the streambed is most intense in the upstream reaches (station EC2). Since armoring will progressively move farther downstream as easily eroded materials are flushed out of upstream locations, we expect that with time, the accumulated materials will be flushed from station EC4, and that station will undergo increased armoring and will have a declining biomass. Such processes can continue, extending further downstream until a significant inflow of sediment laden water enters from a side stream.

Biotic Condition Index

Community tolerance quotients are a part of the biotic condition index developed by Winget and Mangum (1979). The community tolerance quotients are of two types, the actual community tolerance quotient, CTQa, and the predicted community tolerance quotient, CTQp. The predicted community tolerance quotient is based on water chemistry, substrate, and gradient and was determined to be 80 using the directions in Winget and Mangum (1979). CTQa values are a simple arithmetic mean of pre-assigned index values for the taxa present at a given station. The CTQa indices for an idealized stream, based on a combination of taxa collected from Boardinghouse Creek in November 2001, and all taxa collected in Eccles Creek from 2001-2008, are given in Tables 8 and 9. The tolerance index for each taxon, if present, in 2007 (Table 8) or 2008 (Table 9) is listed in the appropriate station column.

Generally CTQa values less than 65 represent high quality waters, while those between 65 and 80 represent situations with moderate to high quality water. CTQa values greater than 80 represent low water quality or stressed systems. The September 2007 stations EC2, EC4, and EC5 had CTQa values of 92, 89.9, and 90 respectively. This contrasts with the fall 2004 CTQa readings of 64.5, 77, and 86.28 which would have placed station EC2 as a high quality system. In the July 2008 stations EC2, EC4, and EC5 had CTQa values of 54.9, 89.3 and 87. Both of the lower stations again showed impact or stress, but the upper station, as in 2004, showed high quality water. These results for EC2 in both the fall of 2004 and in July 2007 do not reflect other data being presented in this report. Of most importance here is the caution made in previous reports, that the CTQa values are based on the average index from just those taxa that are present, and taxa are not weighted for differences in abundance. A site could conceivably have a single individual, and nothing else, but if that organism had been assigned a low tolerance quotient, one would conclude that the water was high quality. In station EC2 the organisms are on rock surfaces, tend to be taxa with low tolerance to siltation, and by default, have a lower tolerance value. These include the mayflies *Cinygmula* and *Drunella doddsei*, the caddisfly *Rhyacophila*, and immature plecopterans.

Comparisons of Community Tolerance Quotient and Biotic Comparison Indices

CTQa values for Eccles Creek can be compared from the 1979, 1990, and 2000 sample periods. These values detected the impact in the 1990s in three stations below the mine (EC1, EC2 and EC4; Table 10), but the impact did not reach the lowest station, EC5. Beginning in 2001, the average CTQa for the stream jumped to 94 and stayed above 70 in 2002, and in June 2003 it was 93. It was 78 in October, 2003; 87 in June 2004; and 76 in October, 2004. In September 2007 the average was 90 and in July 2008 it was 77. The additional inflow has had a more intense impact on the stream than the 1990 detergent spill.

The biotic condition index (BCI) is CTQp/CTQa X 100. This measure (Winget and Mangum 1979) can be used in conjunction with CTQa to generate a broader interpretation of the state of stream systems. Ideally, if all predictors are accurate, a pristine system will have a BCI of 100 (CTQp = CTQa). BCI values below 100 represent a condition where fewer clean water taxa than predicted are present and thus indicate a reduction in the quality of the habitat. Any BCI value above 100 represents communities whose clean water taxa are in greater abundance than predicted. In 35 of the 51 sample stations presented in this report (Table 10), the BCI was over 100. All of the stations sampled in 1979 had BCI values above 100, averaging over 120. Likewise, all but one station, which was directly below the mine, in the 1990-1991 spill series had BCI values above 100. Of the 25 stations sampled since 2001, nine were above 100. Two

Table 8. Tolerance quotients September 2007.

Taxa	above South Fork (EC2)	at Whisky Canyon (EC4)	Lower Eccles (EC5)	Ideal stream (species list, including Boarding-house Creek)
Ephemeroptera: Baetidae: Baetis	72	72	72	72
Ephemeroptera: early instar	72	72	72	72
Ephemeroptera: Ephemerellidae: *Drunella sp.*				48
Ephemeroptera: Ephemerellidae: *Drunella dodsei*				4
Ephemeroptera: Ephemerellidae: *Serratella*				48
Ephemeroptera: Ephemerellidae: *Ephemerella*				48
Ephemeroptera: Heptageniidae: *Cinygmula*		21		21
Ephemeroptera: Heptageniidae: *Epeorus*				21
Ephemeroptera: Leptophlebidae: *Paraleptophlebia*				24
Plecoptera early instar				36
Plecoptera: Chloroperlidae: *Paraperla frontalis*		24		24
Plecoptera: Leuctridae: *Perlomyia utahensis*				18
Plecoptera: Nemouridae: *Malenka californica*		36		36
Plecoptera: Nemouridae: *Zapada*				16
Plecoptera: Perlididae: *Hesperoperla pacifica*				18
Plecoptera: Perlodidae: *Diura knowltoni*				24
Plecoptera: Perlodidae: *Skwalla parallela*				18
Plecoptera: Perlodidae: *Isoperla*				48
Trichoptera: pupae				108
Trichoptera: Brachycentridae: *Brachycentrus*		24		24
Trichoptera: Brachycentridae: *Micrasema*				24
Trichoptera: early instar				108
Trichoptera: Hydropsychidae: *Arctopsyche*				18
Trichoptera: Hydropsychidae: *Hydropsyche*		108		108
Trichoptera: Hydroptilidae: *Hydroptila*				108
Trichoptera: Hydroptilidae: *Ochrotrichia*	108	108		108
Trichoptera: Limnephilidae: *Dicosmecus*				24
Trichoptera: Limnephilidae: *Hesperophylax*		108		108
Trichoptera: Polycentropidae: Polycentropus		108		108
Trichoptera: Psychomyiidae: *Tinodes*				108
Trichoptera: Rhyacophilidae: *Rhyacophila*				18
Trichoptera: Uenoidae: *Neothremma alica*				8

Trichoptera: Uenoidae: *Oligoplebodes*				24
Coleoptera: Dytiscidae				72
Coleoptera: *Heterlimnius*				108
Coleoptera: Elmidae: *Optioservus*		108		108
Coleoptera: Haliplidae: *Peltodytes*				54
Diptera: Ceratopogonidae	108	108	108	108
Diptera: Chironomidae	108	108	108	108
Diptera: Empididae: *Chelifera*	108	108	108	108
Diptera: Empididae: *Hemerodromia*		108		108
Diptera: Empididae: *Neoplasta*		108		108
Diptera: Ephydridae: ***Scatella***				108
Diptera: Limoniidae: *Nr. Rhabdomastix*		108		108
Diptera: Muscidae: *Limnophora*	108		108	108
Diptera: Simuliidae: *Simulium*		108		108
Diptera: Stratiomyidae: *Allognasa*				108
Diptera: Stratiomyidae: *Caloparyphus*		108		108
Diptera: Stratiomyidae: *Euparyphus*		108		108
Diptera: Tipulidae *Dicranota*				24
Diptera: Tipulidae *Limnophila*				72
Diptera: Tipulidae *Tipula*	36	36	36	36
Diptera: Tipulidae *Pedicea*				72
Diptera: Tipulidae *Antocha*				24
Diptera: Phoridae		108		108
Collembola				108
Hemiptera: Saldidae				108
Acari: Hydracarnia		108		108
Ostracoda				108
Copepoda		108		108
Cladocera				108
Mollusca: Gastropoda: *Gyraulus*				108
Mollusca: Spharidae: *Sphaerium*		108		108
Oligochaeta	108	108	108	108
Tricladida: Planariidae				108
Nematoda				108
total	828	2337	720	
n	9	26	8	
CTQa	92	89.9	90	

Table 9. Tolerance quotients July 2008.

Taxa	above South Fork (EC2)	at Whisky Canyon (EC4)	Lower Eccles (EC5)	Ideal stream (species list, including Boarding-house Creek)
Ephemeroptera: Baetidae: Baetis	72	72	72	72
Ephemeroptera: early instar	72	72	72	72
Ephemeroptera: Ephemerellidae: *Drunella sp.*				48
Ephemeroptera: Ephemerellidae: *Drunella dodsei*	4			4
Ephemeroptera: Ephemerellidae: *Serratella*				48
Ephemeroptera: Ephemerellidae: *Ephemerella*				48
Ephemeroptera: Heptageniidae: *Cinygmula*	21			21
Ephemeroptera: Heptageniidae: *Epeorus*				21
Ephemeroptera: Leptophlebidae: *Paraleptophlebia*				24
Plecoptera early instar	36			36
Plecoptera: Chloroperlidae: *Paraperla frontalis*				24
Plecoptera: Leuctridae: *Perlomyia utahensis*				18
Plecoptera: Nemouridae: *Malenka californica*				36
Plecoptera: Nemouridae: *Zapada*				16
Plecoptera: Perlididae: *Hesperoperla pacifica*				18
Plecoptera: Perlodidae: *Diura knowltoni*				24
Plecoptera: Perlodidae: *Skwalla parallela*		18	18	18
Plecoptera: Perlodidae: *Isoperla*				48
Trichoptera: pupae		108		108
Trichoptera: Brachycentridae: *Brachycentrus*		24		24
Trichoptera: Brachycentridae: *Micrasema*				24
Trichoptera: early instar		108		108
Trichoptera: Hydropsychidae: *Arctopsyche*				18
Trichoptera: Hydropsychidae: *Hydropsyche*		108	108	108
Trichoptera: Hydroptilidae: *Hydroptila*	108	108	108	108
Trichoptera: Hydroptilidae: *Ochrotrichia*				108
Trichoptera: Limnephilidae: *Dicosmecus*				24
Trichoptera: Limnephilidae: *Hesperophylax*				108
Trichoptera: Polycentropidae: Polycentropus				108
Trichoptera: Psychomyiidae: *Tinodes*				108
Trichoptera: Rhyacophilidae: *Rhyacophila*	18	18	18	18
Trichoptera: Uenoidae: *Neothremma alica*				8

Trichoptera: Uenoidae: *Oligoplebodes*				24
Coleoptera: Dytiscidae				72
Coleoptera: *Heterlimnius*				108
Coleoptera: Elmidae: *Optioservus*				108
Coleoptera: Haliplidae: *Peltodytes*				54
Diptera: Ceratopogonidae		108		108
Diptera: Chironomidae	108	108	108	108
Diptera: Empididae: *Chelifera*				108
Diptera: Empididae: *Hemerodromia*		108		108
Diptera: Empididae: *Neoplasta*		108	108	108
Diptera: Dixidae: *Dixa*		108		108
Diptera: Limoniidae: *Nr. Rhabdomastix*				108
Diptera: Muscidae: *Limnophora*				108
Diptera: Ptychopteridae: *Ptychoptera*		108	108	108
Diptera: Simuliidae: *Simulium*				108
Diptera: Stratiomyidae: *Allognasa*				108
Diptera: Stratiomyidae: *Caloparyphus*				108
Diptera: Stratiomyidae: *Euparyphus*				108
Diptera: Tipulidae *Dicranota*				24
Diptera: Tipulidae *Limnophila*				72
Diptera: Tipulidae *Tipula*				36
Diptera: Tipulidae *Pedicea*				72
Diptera: Tipulidae *Antocha*				24
Diptera: Phoridae				108
Diptera: *Scatella*		108		108
Collembola				108
Hemiptera: Saldidae				108
Acari: Hydracarnia				108
Ostracoda			108	108
Copepoda		108	108	108
Cladocera				108
Mollusca: Gastropoda: *Gyraulus*				108
Mollusca: Spharidae: *Sphaerium*				108
Oligochaeta		108	108	108
Tricladida: Planariidae				108
Nematoda				108
total	439	11608	1044	
n	8	18	12	
CTQa	54.9	89.3	87	

Table 10. CTQa and BCI values for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	Shiozawa & Hansen 2004	Shiozawa 2005	Shiozawa 2005	Shiozawa 2007	This Report	This Report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003	Oct 2003	June 2004	Oct 2004	Sept 2007	July 2008
	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI	CTQa/ BCI
South Fk. trib. abv. mine (USF2)			59/133	53/151										
South Fork trib. abv. mine (USF)	66/121		49/163	59/136	45/178									
Middle Fork trib. abv. mine (UMF)	69/117		54/148	49/163										
Eccles Creek below mine (EC1)			67/119	108/74										
Eccles Creek abv. S. Fk. (EC2)	64/125	65/123	86/93		73/110		99/81	86/93	87/92	88/91	83/97	65/124	92/87	55/145
South Fork Eccles Creek (SF)	59/136	64/125	55/145											
Eccles Cr. below S. Fk. (EC3)	65/123	55/145												
Eccles Creek at Whisky Can. (EC4)	62/127	61/131	69/116	70/114	63/127	94/85	52/154	69/116	94 /79	76/105	91/88	77/104	90/89	89/90
Lower Eccles Creek (EC5)	59/136	74/108	53/151	55/145 57/140	58/138		66/121	69/116	97/82	71/112	88/91	86/93	90/89	87/92
Average	62/131	64/126	59/140	64/132	60/138	94/85	72/119	75/108	93/86	78/102	87/92	76/ 107	90/88	77/109

of these were fall 2004 samples from stations EC2 and EC4. Station EC2 was again above 100 in July 2008. This conflicts with the inferences generated by other data (see Tables 1, 2) and is illustrated by rating station EC2 (BCI = 145) with the same station in August 1979 (BCI = 123).

Diversity

Diversity indices are a way of combing both number of taxa and relative densities into a single measurement. High diversity index values indicate more taxa and a greater number of individuals per taxon. Low diversity values generally reflect a depauperate fauna in both species and somewhat in numbers. The baseline stations (1979 samples, Table 11) had diversity values ranging between about two to three. The areas impacted by the chemical spill in 1990-1991 had diversities values around one. But in September 1991, the values fell to around 0.5. However, in that same 1991 sample series, the Upper South Fork had a diversity of 0.7, considerably lower than the 1.7 to 1.9 recorded for the previous year. This implies that another factor may have also negatively influenced the stream system in 1990.

Diversity values for all sampled stations were below 1.0 from 2001-2002. In June 2003 station EC2 was 1.3, while stations EC4 and EC5 were slightly below their July 2002 levels but above their October 2002 readings. By October 2003, station EC4 had increased in diversity from 0.96 in June 2003 to 1.43. Station EC2 dropped in diversity to 1.19. Station EC5 was still below 1.0, with a diversity index value of 0.75 which was slightly lower than its June 2003 level. The June 2004 diversity readings showed station EC2 decreasing slightly to 1.17, and station EC4 also fell to a diversity value of 0.98. In contrast, station EC5 increased significantly in diversity to 1.47. The fall 2004 samples indicated that station EC2 was continuing to have a decline in diversity dropping to an index value of 0.94. EC4 increased its diversity reading to 1.17, but EC5 declined to 1.05.

In September 2007 EC2 and EC5 diversity values were 1.10 and 1.14 respectively. These values are not converging towards the pre-impact state. However station EC4 had a diversity value of 2.15, which was close to the values found in the base-line sites in 1979. The high diversity readings from EC4 in 2007 stems in part from the high number of taxa recorded and in part from the relatively low overall density at that site.

In July 2008 the diversity values at all three stations were between 0.95 and 1.2. This is not much change from the previous sample series for EC2 and EC5, but it represents a significant diversity drop in station EC4. This does not support the stations, EC2 included, moving back towards a recovered state. At this time no strong seasonal pattern is discernable and no easily followed trend would suggest that recovery is apparent.

Table 11. Diversity indices based on natural logs for selected studies on Eccles Creek.

	Winget 1980		Ecosystems Research Institute 1992			Shiozawa 2002a	Shiozawa 2002c	Shiozawa 2003	Shiozawa & Hansen 2004	Shiozawa 2005	Shiozawa 2005	Shiozawa 2007	this report	this report
Sampling date	May-June 1979	Aug 1979	June 1990	Oct 1990	Sept 1991	Nov 2001	July 2002	Oct 2002	June 2003	Oct 2003	June 2004	Oct 2004	Sept 2007	July 2008
South Fork tributary above mine, upper site (USF2)			1.63	1.9										
South Fork tributary above mine (USF)	2.63		1.72	1.9	0.702									
Middle Fork tributary above mine (UMF)	2.11		1.66	1.9										
Eccles Creek below mine (EC1)			1.06	0.7										
Eccles Creek above south Fork (EC2)	2.44	1.964	1.58		0.400		0.398	0.836	1.314	1.190	1.165	0.939	1.100	0.956
South Fork Eccles Creek (SF)	3.510	3.322	1.62											
Eccles Creek below South Fork (EC3)	2.450	2.743												
Eccles Creek at Whisky Canyon (EC4)	2.450	3.060	1.22	1.6	0.666	0.757	0.957	0.835	0.955	1.432	0.982	1.165	2.152	1.162
Lower Eccles Creek (EC5)	2.280	2.590	1.24	1.8/ 1.4	0.416		0.829	0.341	0.789	0.750	1.474	1.052	1.141	1.149

Cluster Analysis

Cluster analysis generates a visual representation of relationships among samples or stations. The Bray-Curtis dissimilarity index utilized in this study considers both quantitative counts of individuals within each taxon and the relative densities of those organisms (Poole 1974). A total of 56 station-date combinations were included in the cluster dendrogram (Figure 1). Each station-date combination is a composite of the individual samples taken at each station.

Two highly dissimilar (98%) main clusters were generated. The cluster with the fewest stations (the lowest cluster on Figure 1) consisted of stations from 1990-91, EC1 and EC2, which were impacted by the chemical spill in the 1990s. These were the two stations nearest the mine and would be expected to have suffered the greatest impact from the spill. This cluster also includes the samples taken at station EC4 shortly after the increase in stream discharge in November, 2001. This suggests that EC4 responded with drastic changes in taxa composition in a manner similar to the 1990 perturbations. No other samples fell in this cluster.

All other samples fall into the upper cluster, including the reference data collected in the late 1970s, the side streams sampled in both the 1970s and 1990s, the downstream sites sampled in the 1990s, and the remaining samples taken in the 2001-2008 series. The upper cluster contains two sub-clusters (Figure 1) separating with approximately a 90% dissimilarity. The lower sub-cluster contains the remainder of the 1990 sampling series as well as a number of fall samples taken from the upper (E2) and middle (E4) sampling stations between 2002 and 2004. This sub-cluster is made up of stations that have had a significant impact to their invertebrate community. None of the 2007 and 2008 samples fell into this sub-cluster.

The upper sub-cluster has 3 groups separating at about 70-80% dissimilarity. The lower one (Figure 1) separates at about 80% dissimilarity and contains 2004 samples and one baseline sample from 1979. The upper-most one consists of the 1979 reference samples. The recent Eccles Creek samples would ideally fall into this group if the stations had recovered to pre-discharge conditions. Unfortunately only one station, E5-10-03, fell into this upper group. The remainder of the samples fell into the middle group. This group includes all of the 2007 and 2008 samples as well as majority of the summer 2002-2003 samples. The 2008 samples are most similar to these summer samples.

Figure 1. UPGMA cluster dendrogram of relationships among invertebrate communities from selected stations and dates in Eccles Creek.

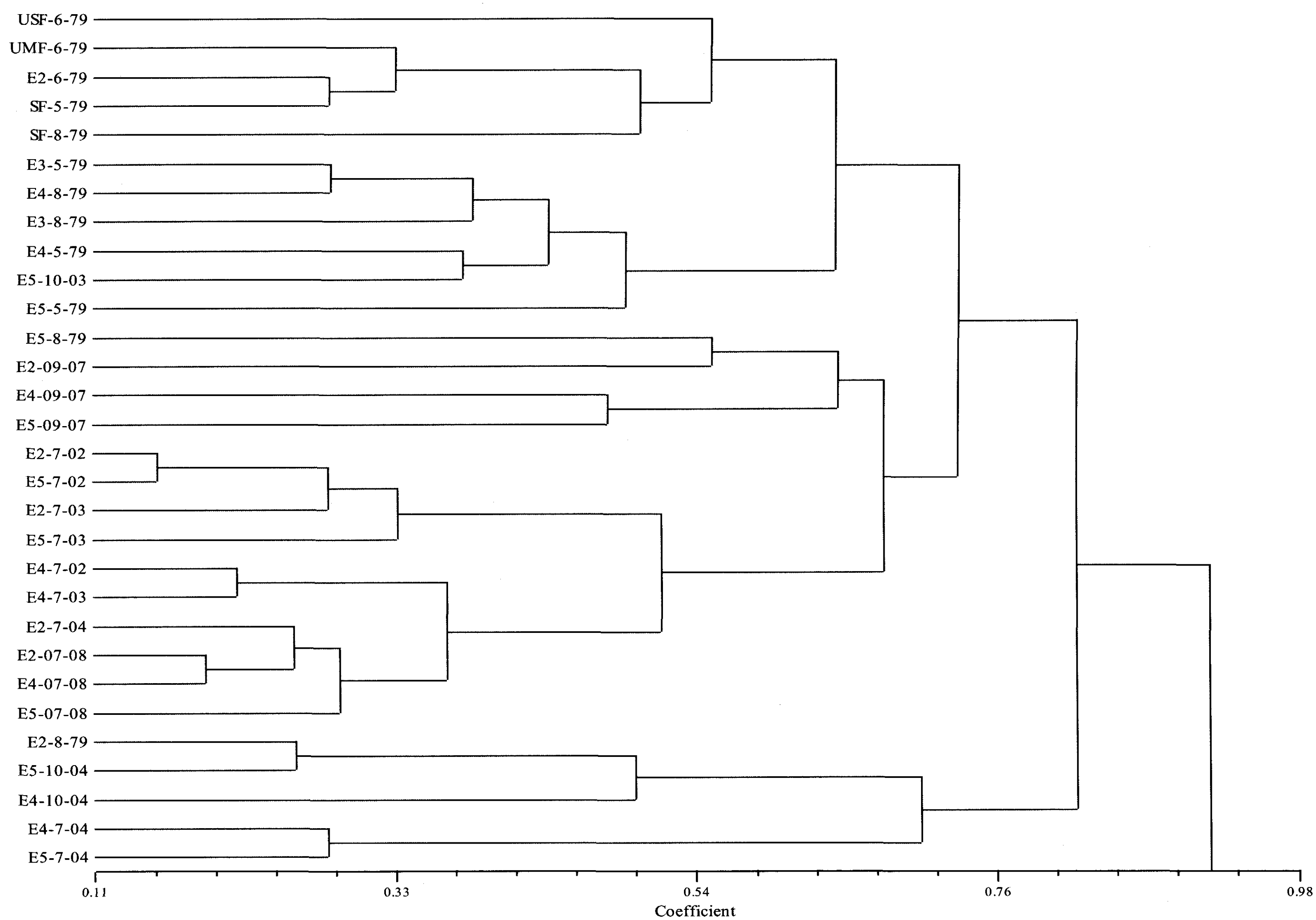
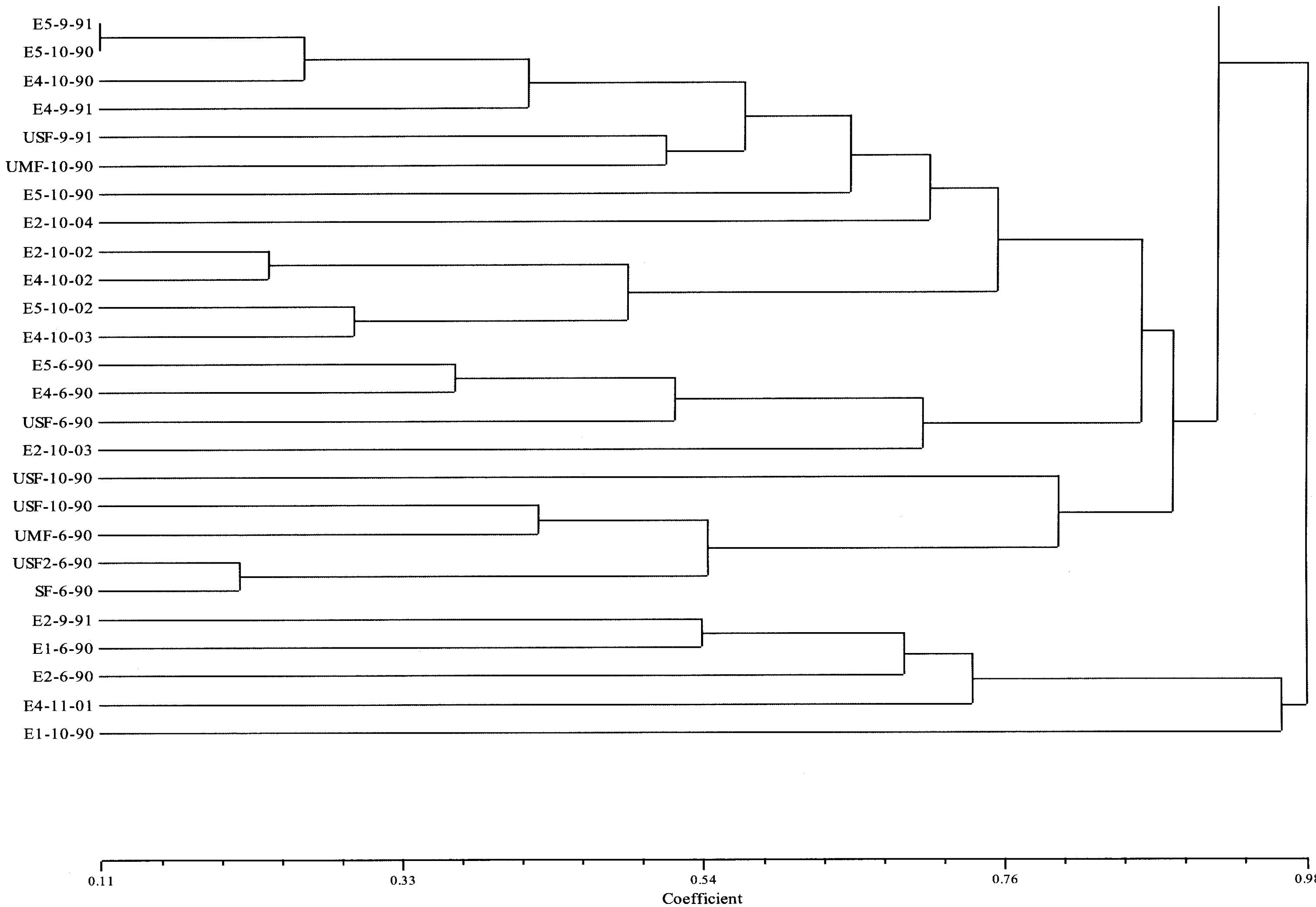


Figure 1 (cont.) UPGMA cluster dendrogram, Eccles Creek.



Correspondence Analysis

Correspondence analysis, an ordination technique (Braak and Smilauer 2002), was run on a reduced data set in order to generate a graphical view of the relationships among the stations sampled in Eccles Creek since the baseline data were collected in 1979. Plots of both the station ordinations and the corresponding invertebrate taxa were generated so that it would be easier to visualize not only station by station associations, but also which invertebrate taxa are driving the separation on the ordination axes. For simplicity only the first two canonical axes were plotted. These two axes only carry a portion of the total variation being explained by the procedure, but they are sufficient for illustrating the associations.

The results (Figure 2) show a clear separation of the samples taken in 1979 (black triangles) from those taken in the 1990s (circles) and those taken in the 2001-2004 series (green, purple and red symbols). Since some of the 1990-1991 samples were taken from locations (tributaries) that were not directly affected by the spill, ellipses were drawn to help delineate those samples. The lower left ellipse thus includes both the 1979 baseline samples and the tributary streams samples in the 1990s. The 1990 tributary series was likely impacted by road construction activities, and those sites have separated to the right on the first ordination axis and up on the second ordination axis, placing them approximately in the center of the ordination plot (Figure 2).

The impacted stations for the 1990 sample period fall mainly in the upper right of the figure (denoted with a blue ellipse). Stations EC1 and EC2 (E1-6-90 and E2-6-90, Figure 2), which were the most heavily impacted by the spill, are central on the plot. Sampling did not continue to recovery, so the trajectory of the stations between 1991 and 2000 are not known. The 2001-2004 sample series forms a discrete grouping in the lower right of the ordination plot (green ellipse in Figure 2). It appears to have a larger scatter in the second ordinal axis and is about equal in spread to the 1990 series on the first ordinal axis.

A plot of the taxa utilized in the analysis (Figure 3) shows which taxa were important in the ordination of samples in Figure 2. Stoneflies (chloroperlids, capniids, perlodids: *Diura*, *Megarcys*) caddisflies (Glossomatidae, *Neothremma*, *Oligophlebodes*, *Onocosmoecus*) and mayflies (*Seretella*, *Cinygmula*, *Paraleptophlebia*) are important groups in establishing the position of the baseline stations from 1979 (Figure 2). The 1990 impact is especially noted in the densities of dryopids and *Ceratopsyche* and to a lesser extent *Brachycentrus, Antocha*, and *Tipula* The high discharge communities of 2001 through 2008 are most notable by *Hemerodromia*, *Paraperla*, *Optioservus*, and the caddisfly *Hydroptilla*.

These two ordinations (figures 2 and 3) give a distinct separation of the types of communities under normal, chemical, and high discharge impacts. The 2001-2008 samples have not shown a shift back to the baseline state. As noted in previous reports this is related to the increased discharge having removed fine sediments and thus armoring the benthic environment. The process also includes precipitation of carbonates as the subterranean source water degases and shifts in pH. The net result is the loss of much of the interstitial space required for a diverse benthic invertebrate assemblage.

Figure 2. Ordination of stations by date using Correspondence Analysis with log X+1 transformed data.

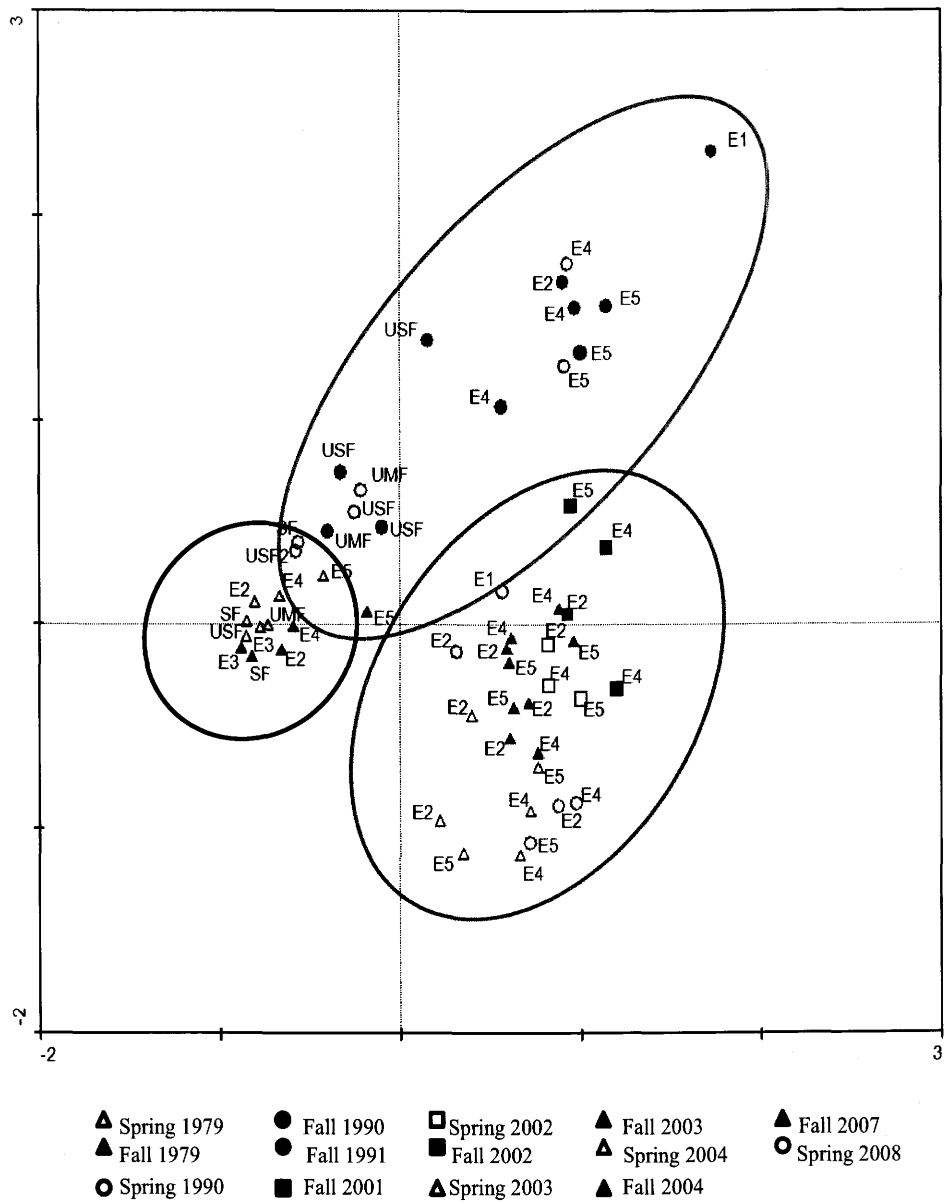
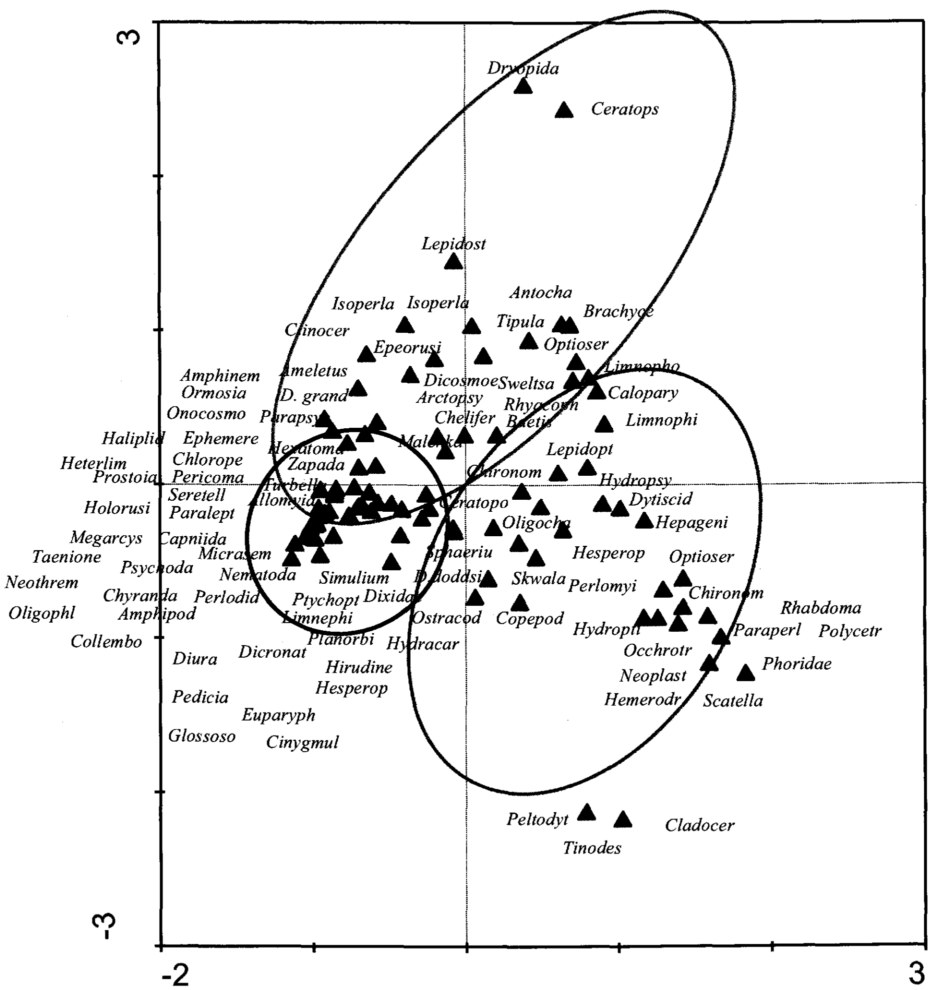


Figure 3. Taxa ordination corresponding to the stations in Figure 2, based on Correspondence Analysis with a log X+1 transformed data. Black circle = 1979 control conditions, blue = 1990 impact conditions, and green = 2001-2008 conditions.



SUMMARY

Number of Taxa

The number of taxa in station EC2has maintained its low level, approximately a sixth of the 1979 count. Station EC4 had been showing a gradual increase in taxa, which peaked in September 2007 at 24 taxa, but the following year, in July 2008, the number of taxa fell to 15. This may be a seasonal trend or the fall 2007 sample estimate may have been an aberrant situation. Station EC5 fell in number of taxa from the 2004 estimates. This reverses a trend that was noted from June of 2003 to October 2004. No clear sustained improvement in total taxa numbers is apparent from this series of samples.

Total Densities

Based on total densities, Station EC5 was near pre-impact numbers in both 2007 and 2008. Likewise EC2 and EC4 were within the range of the 1979 densities in 2008. If higher density denotes greater recovery, then the stations could be considered to have recovered. However in 2004 the densities were much higher than in 2007-08, suggesting over recovery under these assumptions. The cause of the high fall 2007 densities may be in part associated with processing techniques, but those would only reflect on comparisons with the 1979 and 1990 samples. The procedures in most of the 2000 series have been more constant. While a temporary peak of invertebrate numbers seems to have occurred in 2004, those numbers have not been sustained.

Individual Densities

Baetis densities showed an increase through 2004, but in 2007-2008 these numbers had returned to the 2002 levels, suggesting that the 2004 increase was only temporary. *Cinygmula,* appeared to be increasing in 2003, but by the 2007-08 sample series it had fallen to very low numbers. This taxon appears to be unable to establish itself under the condition that existed in Eccles Creek after 2003.

Two species of hydroptillid caddisflies, *Ochrotricha* and *Hydroptilla* showed different responses to the changing conditions in Eccles Creek. *Ochrotricha* was unable to establish high densities, especially in station EC2, despite being relatively abundant in the spring of 2004. Yet *Hydroptilla* was able to colonize Station EC2 (as well as the other stations) with low densities in 2008. This suggests that *Hydroptilla* may be better adapted to stressed environments than *Ochrotricha.*

Hydropsyche appears to have gradually decreased in abundance over the sampling years, falling from over 1,000/m^2 in 2002 to a complete absence of individuals in station EC2 and extremely low densities in EC4 and EC5 by 2008.

Chironomid densities in June 2004 included the highest numbers recorded in the EC4 and EC5 sample series. In addition a trend of lower densities in the fall and higher densities in the spring was readily apparent. This supports a seasonal fluctuation in numbers of midges within the system. But the July 2008 densities are still much lower than found in June of 2004, supporting the hypothesis that June of 2004 was anomalous.

Oligochaetes also show a seasonal abundance signal with higher densities in the spring samples and lower densities in the fall. This could be associated with erosive inputs of fines into the stream with snow melt. By fall most of these fine sediments may be flushed from the system. This group also shows a significant increase in density in June of 2004, but that increase was not repeated in 2008.

Beyond seasonal fluctuations in density, it is apparent that *Baetis,* chironomids, and oligochaetes all increase in the 2004 sampling period, especially in the two downstream stations. This could suggest an adaptation of the community to the increased flows. However, the increase was not sustained in 2007-2008. It therefore appears that the increase in 2004 was transient and a likely cause was the failure of beaver dams which released sands, organic debris and gravel into the stream channel. Other taxa such as *Hydropsyche* decreased from peak October 2002 densities and were missing from the upper station, EC2 in the 2007-2008 samples. *Ochrotricha* and *Cinygmula* showed similar responses. In contrast the microcaddisfly *Hydroptilla* is still found in station EC2 indicating that it is more resistant to the effects of armoring. The individual taxa densities thus suggest that physical changes are taking place. These changes would be expected to be ongoing, as the streambed continues to armor itself with the increased discharge. Future successional changes in the stream community could parallel the dynamics of station EC2 as the armoring induced by sediment starvation continues to extend downstream.

Biomass

The overall mean biomass in Eccles Creek was 9 g/m^2. In contrast Woods and Winter Quarters canyons had a mean biomass of 43 g/m^2. While the biomass estimates in Eccles Creek ranges from 1.82 g/m^2 to 36.7 g/m^2, the mean biomass indicates that the invertebrate standing stock is seldom near the upper end of the range. The September 2007 and July 2008 overall biomass estimates for Eccles Creek are a fifth to a seventh of the respective Woods-Winter Quarters estimates and station EC2 almost always has the lowest in biomass of the three sites. In September of 2007 its biomass was just 7% of that in the Woods and Winter Quarters samples and in July of 2008 the EC2 biomass was about 13% of the Woods-Winter Quarters mean. This reinforces the scenario proposed in earlier reports where the armoring of the streambed is currently most intense in the upstream reaches. The armoring will progressively move downstream as easily eroded materials are flushed out of upstream locations.

CTQa/BCI

The September 2007 CTQa values (92, 89.9, and 90 at stations EC2, EC4, and EC5 respectively) indicate that all three locations have low water quality or are stressed. This contrasts with the fall 2004 CTQa readings of 64.5, 77, and 86.28 which would have placed station EC2 as a high quality system. In July 2008 stations EC2, EC4, and EC5 had CTQa values of 54.9, 89.3 and 87. By this measure, both of the lower stations showed impact or stress, but the upper station, as in 2004, would be rated as a high quality system. Both times that station EC2 had the low CTQa values (=high quality ratings), only seven taxa were collected. This appears to be due to an inherent bias in the computation of the CTQa index. The habitat at station EC2 is scoured, armored, and heavily covered with a calcium carbonate precipitate. Thus it favors invertebrates that live on silt-free, hard surfaces and these taxa, which tend to have low CTQa values can drastically shift the overall CTQa, estimate, especially when low numbers of taxa are present.

The biotic condition index (BCI) adjusts the invertebrate community relative to several physical parameters of the stream system. BCI values below 100 indicate a reduction in the quality of the habitat. BCI values above 100 represent communities whose clean water taxa are in greater abundance than predicted. Of the 25 stations sampled since 2001, 9 had BCI scores above 100. Two of these were fall, 2004, samples from stations EC2 and EC4 and station EC2 was again above 100 in July 2008. This conflicts with the inferences generated by other data and is associated with the bias discussed for the CTQa estimates above.

Diversity

Diversity values do not indicate recovery of the stations. Station EC4 did have a temporary jump in diversity in September 2007, but by July 2008 this site had returned to the low diversity values characteristic of the stream between 2001 and 2008.

Cluster Analysis

Cluster analysis shows a shift in the 2001-2008 communities from very divergent states to being closer to the baseline community. However these communities still have over 70% dissimilarity with the 1979 reference sites. So while the stations are better than they were in 2001, they are still far from being recovered.

Correspondence Analysis

Correspondence analysis also indicates that the stations in 2007-8 have not converged towards the original 1979 baseline conditions. In fact this analysis suggests a slight shift away from the 1979 control state in the most recent sampling set. The 2001-2008 samples form a discrete group in ordination space which is separate from the 1979 samples. This reinforces their differences with the unimpacted stream community structure. This analysis indicates that Eccles Creek has not yet begun a trend back towards the normal state.

Conclusions

Total densities and the CTQa measures indicate that some of the sites may have improved considerably. The CTQa measure indicates that 3 of the 25 station samples since 2001 have very good water quality. The BCI indicates that 9 of 25 stations were of good quality. Yet the number of taxa, individual taxa densities, biomass, diversity indicies, cluster analysis, and correspondence analyses all indicate that Eccles Creek has not yet recovered from the increased discharge. The cluster analysis suggests a slight shift of the three stations towards the reference communities of 1979, but they are still highly dissimilar to those communities. Correspondence analyses indicates that the communities have changed little since 2001.

Given the gradient of the stream channel and the increased discharge, it is unlikely that the stream can return to its pervious state. It originally would have an established a sediment transport rate based on seasonally low flows with occasional flood events. The equilibrial channel for the present higher flows is one with a much greater rate of transport of loose bedload. This situation is enhanced by the input of sediment-free water which generates an armoring processes much like that below reservoirs. Since the water also has a high calcium bicarbonate content, which can be enhanced by anoxic conditions in the discharge waters, significant precipitation of calcium carbonate would be expected as the water degasses. This can further armor the substrate.

Thus, it is unlikely that, in the long term, the stream can recover without a reduction in flow or an increased input of loose, coarse material into the stream. As noted previously, the sustained high discharge and lack of interstitial space in the stream bed does not favor retention of detritus (Shiozawa 1983) nor the development of a diverse invertebrate community (Cummins 1974). The armoring will continue to extend downstream as sediments available for transport gradually disappear from the upstream streambed.

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APPENDIX C

Legal Financial, Compliance and Related Information

Annual Report of Officers
As submitted to the Utah Department of Commerce

Other change in ownership and control information
As required under R645-301-110

CONTENTS

None – Submitted by V. Miller for all CFC Mines in March 2010

APPENDIX D

Mine Maps

As required under R645-302-525-270

CONTENTS
None – See Appendix B

APPENDIX E

Other Information

In accordance with the requirements of R645-301 and R645-302

CONTENTS
None